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VOL. 18 JULY, 1927 No. 1

CONTENTS

Manganese in Waterworks. By C. A. H. von Wolzogen Kuhr. 1
A Program for Protecting Chicago's Land Tunnel System. By H. H. Gerstein and Arthur E. Gorman 32
The Electrolysis Survey Committee of Baltimore City. By H. Carl Wolf 44
Experiences with Goose-Necks, on Service Connections, of Lead, Wrought Iron and Copper. By Emil L. Nuebling 51
Progress of Water Treatment on Railroads. By R. E. Coughlan 55
Operation at the New Water Softening Plant at Springfield, Ill. By Charles H. Spaulding 60
Some Notes on Small Diesel Engines. By Huldreich Egli. 71
A Study of the Chlorine Absorption of Water. By Jacob R. Meadow and Harrison Hale 75
Water Purification. By Paul Hansen 82
Dramatizing Water Works Reports. By J. R. Cortese ... 96
Water Rates. By J. Clark Keith 100
The Fort Pierce Filter Plant. By F. P. Larmon 112
Disinfection of Water Mains. By Charles H. Eastwood .. 114
The White River Survey. By W. F. King 117
Comment on a Recent Report on "Standard Methods of Water Analysis." By Emery J. Theriault 121
Discussion. Electrolytic Chlorination 129
Obituary:
John Ericson 136
Fred. C. Smith 139
Oscar E. Bulkeley 140
Resolution on Death of Merritt H. Smith 142
Abstracts 143

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MANGANESE IN WATERWORKS

BY C. A. H. VON WOLZOGEN KÜHR[1]

The investigation of the part which manganese plays in waterworks was carried out with regard to the Amsterdam dune water. The results which were obtained are of general importance, so that they apply to other kinds of water as well.

In an article written by J. Tillmans,[2] he shows the necessity of removing manganese from drinking water, by stating the bad effects produced by the use of water containing manganese, such as:

1. The forming of dark colored manganese deposit in the pipes, from which all difficulties originate.

2. The forming of brown spots in linen, during the process of washing, as water containing manganese, when mixed with alkali, such as soda and soap, secretes manganic peroxide under the influence of the oxygen of the air.

3. In papermills brown spots are formed on the paper, in breweries the fermentation is disadvantageously affected, while in dye-works the colors become spotty.

The unpleasant consequences of the use of water containing manganese can, according to Tillmans, be effected by even a very small quantity of manganese (Mn), for instance 0.5 mgm. per liter.

[1] Chemist and Bacteriologist, Water Supply Division, Amsterdam, Holland.

[2] Journal für Gasbeleuchtung und Wasserversorgung, LVII Jahrgang, No. 29, p. 713.

As the raw dune water contains manganese, it was therefore necessary to remove it.

THE ORIGIN OF MANGANESE IN DUNE WATER

W. G. N. van der Sleen[3] says that the largest quantity of manganese in dune sand occurs as a corruption of iron-ore, which in the same way as iron dissolves in water containing carbonic acid. Also in the ferrous carbonate concretions of the deeper loam formation in the earth, this writer finds a comparatively large quantity of manganese.

The difficult oxidation of the watery solution of manganous bicarbonate by the oxygen of the air ,was shown to be associated with the hydrogen ion concentration of the solution.

MANGANESE IN CONNECTION WITH MICROBIOLOGICAL PROCESSES

The alterations, which manganese-compounds undergo under the influence of microbes, were studied by M. W. Beijerinck[4] and N. L. Söhngen.[5] The former described a certain group of bacteria and fungi, which occur in the soil and are able to oxidize a manganese compound such as manganous carbonate, into manganese-peroxide. A further examination by Söhngen showed that manganic and manganous compounds can interchange, while he also pointed out that these processes can also take place in the soil.

By former examinations, it is clearly shown that by the biological oxidation process the dissolved manganous compounds can be transformed into undissolved manganic oxide, and that inversely by biological reduction, which always takes place in anaerobic processes, undissolved manganic compounds can pass into dissolved ones. L. Pasteur[6] already observed that the aerobes take the anaerobes in protection, that is to say, the aerobes make the existence of the anaerobes possible.

In this connection Söhngen says, also, that the anaerobic processes take place, not only in anaerobic cultures, but also in aerobic media, after the removal of the oxygen by the growth of microbes, especially in these so-called aerobic cultures, which really only contain on the

[3] Bijdrage tot de kennis der chemische samenstelling van het duinwater in verband met de geomineralogische gesteldheid van den boden, p. 47–49.
[4] Verzamelde geschriften, Dl. V, p. 141.
[5] Centralbl. f. Bakt., 2te Abt., Bd. 40, 1914, p. 545.
[6] Lafar. Handl. d. Techn. Mykologie, 1904–1907, Bd. I, p. 577.

surface an extremely thin layer of liquid containing oxygen. It goes without saying that this principle is not only applicable to soil, but also to water, in which anaerobic and aerobic conditions occur simultaneously, under which circumstances manganese is transformed into manganous carbonate (with superabundance of carbon dioxide in manganous bicarbonate) and manganous sulfate. This is also applicable to the deeper layers of the dunes[7] and also to the mud, settled from the water in the canals of the drainage area and the reservoir of all the dune water, in which the reduction of sulfate very generally occurs as a specific anaerobic process.

IN WHAT FORM IS MANGANESE FOUND IN DUNE WATER?

Originally manganese is dissolved in raw water as manganous sulfate and manganous bicarbonate; to speak more precisely, manganese occurs in ion state. This is not stable, however, in a very dilute watery solution as hydrolysis appears, as shown by the equilibrium equation:

$$MnSO_4 + 2H_2O \rightarrow Mn(OH)_2 + H_2SO_4$$
$$Mn(HCO_3)_2 + 2H_2O \rightarrow Mn(OH)_2 + 2H_2CO_3$$

Manganese would thus, as Tillmans[8] supposes, occur in the water as $Mn(OH)_2$, as by dilution the chemical equilibrium is entirely moved to the right. With ordinary chemical-analytical methods it is impossible to determine in what form manganese occurs in raw water, because the necessary processes easily change its value, so that the original state in which the manganese existed, is lost.

THE RAW DUNE WATER AND THE REMOVAL OF MANGANESE FROM IT

The raw water found in the dunes is led through series of open shallow canals and collected in a general reservoir, out of which the raw water is conducted through a pipe to the purifying-works at Leiduin. The purification of the water is effected here by slow filtration through sand, preceded by a more rapid filtration through coarse gravel.

Although during the passing of the raw water through the canals and

[7] C. A. H. von Wolzogen Kühr. On the occurrence of sulphate reduction in the deeper layers of the earth. Proceedings, Vol. XXV, Nos. 5 and 6, Koninkl. Akad. van Wetenschappen te Amsterdam.

[8] Loc. cit., p. 716.

the reservoir to the purifying station no visible deposit of manganese takes place, the color of the rapid filter gravel, which was originally light colored, is striking in its dark brown tint, by which it shows a great likeness to roasted coffee-beans. Not only the deposit on the gravel, principally consisting of manganese and iron oxide, but also the mud of the rapid filters is dark brown, as it is composed of the same materials.

Sand filters, fed by raw dune-water instead of water from the rapid filters, also prevent manganese from passing. For the present it is sufficient to say that the oxidation of this takes place in the same way as in the rapid filters.

EXAMINATION OF THE COMPOSITION OF THE SEDIMENT OF MANGANESE IN THE RAPID FILTERS

As the rapid filters are so arranged that the oxidation processes of different elements of the raw water play an important part, the oxidation of manganese is very striking. By chemical analysis it appears that the brown indissoluble compounds in the rapid filters consist of ferric and manganic oxide. The structure of the latter was found employing the iodometrical and oxidimetrical method of analysis.

Iodometrical method of analysis

Chiefly this method is based upon the following facts. All manganese oxides can be represented by the formulae $(MnO)_xO_y$, in which x and y represent simple, whole numbers. If one treats manganese oxides with concentrated hydrochloric acid, the reaction takes place according to this scheme:

$$(MnO)_xO_y + 2(x\ y)HCl \rightarrow (x\ y)H_2O + xMnCl_2 + yCl_2 \qquad (I)$$

The coefficient y, which represents the degree of oxidation of manganese oxide, is to be found by stating the quantity of chlorine, which is set free. If however, one adds to manganese oxide dissolved in hydrochloric acid a surplus of alkali and afterwards an agent of oxidation in the form of peroxide of hydrogen or a clear solution of chloride of lime, then manganic dioxide (MnO_2) will appear.[9]

Every manganese oxide can be changed, therefore, by being dissolved in hydrochloric acid, and followed by oxidation in an alkaline

[9] W. Böttger. Qualitative Analyse, 2te Aufl., 1908, p. 213.

medium, into manganic dioxide, represented by the following reaction:

$$(MnO)_xO_y + x(O) \rightarrow xMnO_2 \qquad (II)$$

The coefficient, x, which represents the quantity of base in manganese oxide, is to be found by stating the quantity of manganic dioxide, which can be done after the equation (I).

One starts with two equal weights of dried sediment of rapid filters and treats the first quantity in the well known apparatus

TABLE 1

Manganese tests by iodometric method

All manganese oxides = $(MnO)_xO_y$, in which x and y are simple, whole numbers.

FOR THE STATING OF X USED 50 MGM. MUD-POWDER⟶MnO_2	FOR THE STATING OF y USED 50 MGM. MUD-POWDER IN ORIGINAL CONDITION	THE VALUES OF x/y IN $(MnO)_xO_y$ FOR THE DIFFERENT MANGANESE OXIDES	THE VALUE OF x/y OBTAINED FROM THE EXAMINED UNKNOWN MANGANESE OXIDE
Used number cubic centimeters 1/100 N thiosulfate solution	Used number cubic centimeters 1/100 N thiosulfate solution	MnO_2 x/y = 1	
1. Anal. 30.2	31.9	Mn_2O_3 x/y = 2	x/y = $\frac{31.2}{31.4}$
2. Anal. 34.8	30.9		= 0.99
3. Anal. 30.0	32.6		Rounded off:
4. Anal. 32.7	30.1	Mn_3O_4 x/y = 3	x/y = 1
Average 31.2	31.4		So the unknown manganese oxide is MnO_2

of Stortenbeker,[10] and in the same way also the second quantity. In the first test the unknown manganese oxide is converted into manganic dioxide, then one finds from both analyses the proportion, x/y. As this represents for each of the manganese oxides a definite value, from this the composition of the examined manganese oxide follows immediately. Table 1 gives a general view of the result obtained with the sediment, dried at 110°C., containing the brown manganese oxide, by the iodometrical method.

[10] Zeitschr. f. anal. Chem., 29, 1890, p. 272.

Oxidimetric method of analysis

In principle this is quite the same as the iodometrical method. The manganese oxide can be decomposed by oxalic acid by adding sulfuric acid. The surplus of oxalic acid is titrated with potassium permanganate, so that can be stated how much oxalic acid was used by the manganese oxide. If one repeats this determination with the same quantity of this matter, after it has been previously converted into MnO_2, then in the same way as by the iodometrical determination the value of x/y is to be found. The reactions are:

$$(MnO)_xO_y + (COOH)_2 \rightarrow xMnO + 2CO_2 + yH_2O \quad (I)$$
$$(MnO)_xO_y + x(O) \rightarrow xMnO_2 \quad (II)$$

in which the coefficients x and y represent, respectively, the quantity of base and the degree of oxidation of the manganese oxide.

The mud of the rapid filters containing manganese, required for the research, is obtained by a violent shaking of washed gravel in wide-mouthed bottles. The mud formed by the rubbing of the gravel stones against each other is then collected and dried. One may use directly the mud of the rapid filters, which, however, is more largely mixed with iron oxide. As it is necessary to remove calcium, which is present, the mud is warmed with diluted acetic acid for the decomposition of calcium carbonate and washed with hot water until no more calcium can be detected. Afterwards the mud is dried and sifted till it becomes a fine powder. The removal of calcium carbonate had the advantage that the mud became richer in manganese oxide.

In table 2 the results obtained by the examination of the mud-powder, dried at 110°C., are shown.

It might be supposed that one had to do with a mixture of manganese oxides, which appear on the analysis as MnO_2. This supposition, however, is for stoichiometrical reasons, which can not be dwelt upon here, untenable.

THE ANALYSIS OF THE COMPONENT PARTS STICKING TO THE GRAVEL

An examination as to the quality of the dark material, which adheres to the gravel of the rapid filters, showed, that besides manganese oxide, iron oxide, silica, calcium and magnesium carbonate and organic matter (detritus and material of microbes), were the component elements. An analysis of the component parts sticking to the gravel, gave the results shown in table 3.

The analysis shows that the greater part of the materials sticking to the gravel of the rapid filter contains manganic peroxide, so that the dark brown color of the gravel is easily understood.

TABLE 2

Manganese tests by oxidimetric method

All manganese oxides = $(MnO)_xO_y$, in which x and y are simple, whole numbers.

FOR THE STATING OF X USED 50 MGM. MUD-POWDER $\longrightarrow MnO_2$	FOR THE STATING OF y USED 50 MGM MUD-POWDER IN ORIGINAL CONDITION	THE VALUES OF x/y IN $(MnO)_xO_y$ FOR THE DIFFERENT MANGANESE OXIDES	THE VALUE OF x/y OBTAINED FROM THE EXAMINATION UNKNOWN MANGANESE OXIDE
Used number cubic centimeters 1/100 N permanganate of potassium	Used number cubic centimeters 1/100 N permanganate potassium	MnO_2 x/y = 1	
1. Anal. 11.5	11.5	Mn_2O_3 x/y = 2	$x/y = \frac{11.34}{11.34} = 1$
2. Anal. 11.2	11.2		
3. Anal. 11.3	11.3		
4. Anal. 11.5	11.3	Mn_3O_4 x/y = 3	So the unknown manganese oxide is MnO_2
5. Anal. 11.2	11.4		
Average 11.34*	11.34		

* This value is not to be compared with that obtained by the iodometrical method, because here a powdered mud with a large mixture of manganese oxide is used.

TABLE 3

Composition of the materials adhering to the gravel

MATERIALS	AMOUNT COMING FROM 10 GRAMS GRAVEL OR 0.150 GRAMS OF ADHERING MATERIAL	EXPRESSED IN PER CENT OF TOTAL QUANTITY OF ADHERING MATERIAL
	grams	
MnO_2	0 050	33.3
Fe_2O_3	0.028	18.7
SiO_2 and elements of ash	0.003	2.0
Ca- and $MgCO_3$	0.027	18.0
Organic matter	0.042	28.0

EXAMINATION OF MUD FROM THE RESERVOIR

As for the question whether the rapid filters form the first stage, where manganese is deposited out of raw water, the answer is in the

negative, since examination proved that the mud from the reservoir as well as that from the canals contained manganic oxide. However, the quantity is small, which seems to be due to the reduction of sulfate in the mud, as noted earlier herein. As is shown there, manganese deposit from the raw water can be dissolved again by the above mentioned process. This is probably one of the reasons why the raw water, notwithstanding its long journey through the canals in the dunes, still contains very little manganese, when it arrives at the purifying station.

The mud consisted of an homogeneous greenish-black mass with a very slight putrid smell. With diluted hydrochloric acid much carbonic acid and hydrogen sulfide developed, the former gas originating from calcium and magnesium carbonate, the latter from iron-sulfide, from which the mud takes its dark color and which is formed by reduction of sulfate. If the water, which the mud contains, is separated from it, we find therein a quantity of manganese not higher than that in raw water, which on an average is nearly 0.3 mgm. per liter.

If the fresh mud is extracted with diluted hydrochloric acid or acetic acid, and then washed well with hot water and afterwards dried, then the powdered mud thus treated, yields when warmed with 10 per cent oxalic acid, notable quantities of dissolved manganese. From the specific effect of oxalic acid upon manganese oxides in general, it may be concluded, that in the mud manganese occurs in the form of oxide.

THE QUALITY OF THE MANGANESE OXIDE IN THE MUD OF THE RESERVOIR

The application of the oxidimetric method, mentioned above should be preceded by the discarding of the easily oxidizable organic matter, as otherwise the titration with permanganate of potassium is impossible. This is effected by prolonged extraction of the mud by dilute hydrochloric acid, by which at the same time calcium was removed, and afterwards in the same way with dilute ammonia solution. By the removal of the above mentioned component parts, the quantity of manganese oxide was increased, so that the analysis can be started with a small quantity. Table 4 gives a review of the results of the analysis.

In the mud, therefore, manganese occurs too in the form of manganese dioxide, so that it is obvious, that this is the general state, in which it settles from raw water. One might think that by a long

continued extraction of the mud with hydrochloric acid and ammonia, it might be possible to discard the lower manganese oxides, which can occur mixed with manganese dioxide. This however is not the case, as by examination I have proved, that Mn_2O_3 as well as Mn_3O_4 in long continued contact with dilute acid solutions and ammonia N/1 to N/2 did not notably dissolve. Also, if through the above mentioned preparatory treatment of the mud a very little of the above mentioned manganese oxides should be dissolved, then enough of the two lower manganese oxides would remain in the mud to be apparent.

TABLE 4

All the manganese oxides = $(MnO)_xO_y$, in which x and y are simple, whole numbers.

FOR THE STATING OF x USED 1½ GRAMS MUD-POWDER → MnO_2	FOR THE STATING OF y USED 1½ GRAMS MUD-POWDER IN ORIGINAL CONDITION	THE VALUES OF X/Y IN $(MnO)_xO_y$ FOR THE DIFFERENT MANGANESE OXIDES	THE VALUE OF x/y OBTAINED FROM THE EXAMINED UNKNOWN MANGANESE OXIDE
Used number cubic centimeters 1/10 N permanganate of potassium	Used number cubic centimeters 1/10 N permanganate of potassium	MnO_2 x/y = 1	
1. Anal. 1.2	1.2		x/y = 1.35 / 1.30
2. Anal. 1.5	1.4	Mn_2O_3 x/y = 2	= 1.03
Average 1.35	1.30	Mn_3O_4 x/y = 3	So the unknown manganese oxide is MnO_2.

If one examines the quantity of deposited manganese oxide in the mud of the reservoir and the different canals, one finds this is very small, as comparatively large quantities of organic matter, iron oxide, silica, calcium and magnesium carbonate (principally the first named) are deposited.

THE AMOUNT OF MANGANESE IN THE MUD OF THE RESERVOIR AND THE CANALS

The compounds of manganese are determined as manganese dioxide. The result of the examination was that the dry mud of the reservoir contained 0.1 per cent, that of the canals 0.05 per cent manganese (Mn). The larger amount of manganese of the mud in

the reservoir of 0.1 per cent is easily understood when we keep in mind that the water of the canals carries the deposited manganese partly as suspension to the reservoir, where it is partly deposited.

Sulfate reduction also occurred in the mud of the canals just as in the mud of the reservoir. That which was said earlier about the dissolving of manganese under the influence of anaerobic processes, as the sulfate reduction, is also entirely applicable to the mud in the canals.

THE CONDITIONS FOR CHEMICAL OXIDATION OF MANGANOUS COMPOUNDS IN DUNE WATER

Of importance is the question whether the oxidation of manganese in dune water can be caused by the oxygen of the air. To examine this, pure manganous carbonate was brought into suspension in dune water (filtered), and in this a strong stream of carbonic dioxide was led for two hours. After filtration of the water, a current of air was led through the clear solution for fifteen hours, for the removal of the surplus of carbon dioxide. By this only a small white deposit was noticed, consisting of manganous carbonate. By a determination of manganese it was proved that the dune water contained, as a result of the above mentioned treatment, 5.9 mgm. manganese (Mn) per liter in solution. Of this manganous carbonate solution, by the addition of indicators, the hydrogen exponent was almost exactly determined. The pH lies between 8.8 and 9.6. The passing of air in this solution for more than twelve hours did not show the slightest oxidation of manganese, otherwise shown by the forming of a brown flaky deposit. A chemical oxidation is for this reason excluded. The hydrogen exponent of the solution was determined, after adding dilute alkali, as well by the effect of air or peroxide of hydrogen. Just a deposit of maganese peroxide was formed. The pH lay between 9.8 and 10.1 and was about 10, as well by the effect of peroxide of hydrogen as by mixing with air, although in the first case the brown coloring by the deposited manganese was formed almost immediately, in the second case within a quarter of an hour. The conclusion from this observation is, that the chemical oxidation of a saturated solution of manganous bicarbonate in dune water needs a larger hydrogen exponent than this solution naturally contains, namely a pH = 10.

The raw dune water has an average pH = 8.1, therefore, considerably less than 10, so that this may be the reason why there is no ques-

tion of a chemical oxidation of dissolved manganous compounds in dune water.

It might be supposed that, in the rapid filters, where the oxidation of ferrous iron into ferric iron can take place, the iron oxide thus formed, perhaps in a catalytic way, can cause the oxidation of dissolved manganese into manganese peroxide. For the examination 10 cc. of the above mentioned solution of manganous bicarbonate was poured into two Erlenmeyer flasks. To one of the latter was added a little solid ferrous sulfate, afterwards both were mixed with air and a few drops of peroxide of hydrogen of 3 per cent were added and slightly warmed. In the flask with ferrous sulfate a brown deposit of iron oxide was formed, which was filtered and washed with hot water; in the other a thin white deposit of manganous carbonate was formed. The two filtered solutions were treated after the method of Marshall, by which the dissolved manganese, by the oxidation of nitrogen acid and ammonium persulfate, and the addition of a little silver nitrate, was changed into permanganate. By colorimetric comparison the color of the permanganate was the same in both cases, so that with the iron no manganese is oxidized. This was moreover proved by dissolving the precipitation of iron in nitrogen acid and also by treating it after the Marshall method, whereby no permanganate was formed.

THE SEARCH FOR MANGANESE MICROBES IN DUNE WATER

From the foregoing it is evident, that as taught by experience, oxidations of dissolved manganese into manganese peroxide take place as well in the rapid filters as in the canals. The solution of this problem is entirely of a microbiological nature as will be seen in what follows. The bacteriological search after the microbes in raw dune water, which cause the manganese oxidation, was carried out after the method of M. W. Beijerinck.

The development of microbes took place on plates of dune water agar, in which freshly precipitated manganous carbonate was evenly suspended, with or without any intentional addition of an organic source of carbon. As a source of nitrogen I used ammonium-sulfate, nitrate and chloride without perceptible difference in the development of the manganese bacteria colonies. For the examination of raw dune water, as well as of the mud of the rapid filters for the presence of manganese microbes, a culture plate of the following composition was used.

Dune water	100	cc.
Agar	2.5	grams
Calcium acetate	1	gram
$(NH_4)_2SO_4$	0.1	gram
K_2HPO_4	0.05	gram
$MnCO_3$	1	gram

With a platinum wire, bent in a right angle, moistened with raw water or a suspension of mud from the rapid filters, inoculation streaks were drawn across the plate. At 25°C. after seven days the streaks, which were first drawn, were visible by the brown color of the developed colonies of the manganese microbes. Not until after two or three weeks were the separate colonies in the last streaks developed, which especially with the use of a magnifying glass were distinctly visible.

By microscopical examination of the colonies under a feeble magnification different colonies could be observed, evidently belonging to different kinds of microbes. Some kinds of colonies showed on their surface definite shape, others simply showed a slight wave, while colonies were found also with rays outside the nearly circular outline. In the middle the colonies were usually dark brown to black, more to the outline somewhat lighter, showing often on the extreme edge a clearly marked yellow or yellow-brown color. If one lets the light fall obliquely upon the colonies, their surface is usually shiny. Figure 1 gives a picture of different manganese-bacteria colonies, to which is added the transverse section. The difference in hue, shown in black, represents the variations, which really are from brown to black. The manganese-bacteria consist of shifting and stationary cells. As a rule they are stationary and occur as mono and diplococci, rods and bacteria united in pairs. The diameter of the monococci was 0.7–1.4 μ. The diplococci and rods were nearly of the same length, namely 2.6–3.3 μ, while the thickness was 0.7–0.8 μ.

Less frequently there appeared on the plate brown colonies, which consisted entirely of shifting bacteria. These were found on a plate of manganous carbonate, infected with mud from the rapid filters and consisted of very small rods of 4 μ in length and 0.3 μ in thickness. I succeeded with the aid of the coloring method of Zettnow, in making of these shifting bacteria a cilia-preparation, though the culture was nearly twenty-one days old, while as a rule for such a coloring only bacteria of a very fresh culture can be used. The shifting bacteria were shown to possess only one polar cilium the length of which was

two or three times that of the rod. Seen through the microscope the bacteria appear as brown to yellow-brown masses, while the separate cells without motion of their own, show as a rule the Brownian motion especially the very small cocci.

The brown manganese oxide, formed by the microbes from the manganous carbonate, may often be seen lying in the cells, an observation upon which more will be said later on.

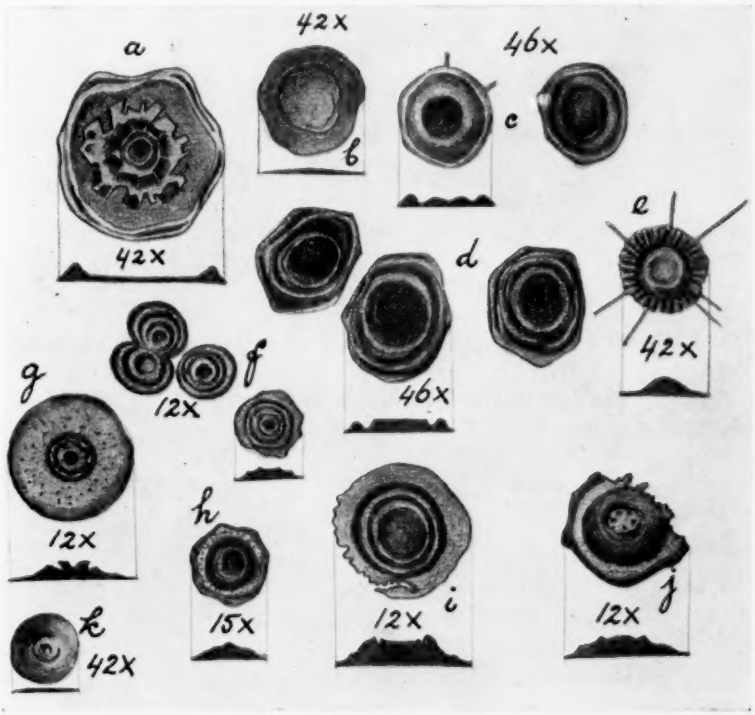

FIG. 1. MANGANESE BACTERIA COLONIES

a, *b*, *e*, *h* and *k* are ±3 weeks old. *c* and *d* are ±4 weeks old. *f*, *g*, *i* and *j* are ±6 weeks old.

If one notices the difference in color of the various colonies, which on the same plate can be light to dark brown and even pitch black, this is to be ascribed to the quantity of manganese oxide deposited in the colonies. In the black colonies this quantity is relatively greater than in the lighter colored ones, which is to be attributed to the degree of the manganese oxidation.

FIG. 2. GROWTH OF MANGANESE BACTERIA ON A MANGANOUS CARBONATE PLATE

The dark matter is manganic dioxide (MnO_2)

FIG. 3. GROWTH OF A MANGANESE FUNGUS ON A MANGANOUS CARBONATE PLATE

The dark matter is manganic dioxide (MnO_2)

Figure 2 shows the growth of the manganese bacteria on a plate of manganous carbonate. In the inoculation streaks the dark manganese oxide is formed.

Besides bacteria, occasionally a fungus was isolated from the mud of the rapid filters, which strongly formed manganese oxide. The composition of the feeding ground was the same as the above mentioned, except that here as source of nitrogen was used 0.1 per cent NH_4NO_3. The growth of the fungus colonies was noticeably quicker than that of the bacteria. After nine days development at 25°C., the diameter of the colonies was nearly 5 mm., after twelve days 18 mm., and after twenty days 28 mm., while the black spots had the same dimensions.

Figure 3 shows how the fungus forms the dark manganese oxide on a manganous carbonate plate.

The attempt to determine the fungus, only led to the determination of the family Pyrenochaeta,[11] as for determining the species the necessary details were wanting. The fungus could easily be held in culture by inoculating, contrary to the manganese bacteria. The latter grew worse and worse, by inoculating for obtaining and maintaining pure cultures while their power of oxidation of manganous carbonate also decreased considerably.

EXAMINATION OF THE COMPOSITION OF THE MANGANESE OXIDE FORMED BY MICROBES

Just the same as in the examination of the composition of the manganese oxide in the mud of the canals and the rapid filters, it is here also necessary to determine the composition of the brown product formed from the manganese carbonate of the culture plate.

That the brown matter is a manganese compound, is proved by the following facts:

1. The decomposition of peroxide of hydrogen, while oxygen is formed.
2. The formation of iodine from potassium iodide in concentrated acid solutions, which colors starch blue.
3. The formation of chlorine from concentrated hydrochloric acid.
4. The specific reduction by oxalic acid, by which discoloration takes place, while at the same time much carbon dioxide is formed.

[11] The determination of the Pyrenochaeta family was achieved by Prof Dr. Joha. Westerdijk, to whom I offer my heartfelt thanks.

5. The solubility with a dark brown color in concentrated sulfuric acid.

The composition of the manganese oxide was found by:

1. Determination of the quantity of manganese (Mn).

2. Determining the above mentioned value of x/y, by the oxidimetric method.

For that purpose the brown matter was collected from the culture plate, rinsed in diluted warm acetic acid, afterwards washed with hot water and dried to a constant weight at 120°C.

The determination of the quantity of manganese as $MnSO_4$[12] resulted in the values 63.0 and 62.7 per cent Mn, which come nearest to the theoretical value of 63.22 per cent Mn and MnO_2.

For x/y, determined by the oxidimetric method, the value of 1.05, was found which belongs to MnO_2. The conclusion is, therefore, that the manganese microbes on the culture plates, just as in the rapid filters, oxidize the manganous compounds into MnO_2. Those microörganisms are usually present in raw dune water, so that the occurrence of MnO_2 in the canals, the reservoir and the rapid filters is easily explained.

THE MICROBIOLOGICAL MANGANESE OXIDATION IN CONNECTION WITH THE HYDROGEN-EXPONENT OF THE FEEDING MEDIUM

We have already seen that the hydrogen exponent plays an important part in the chemical oxidation, namely, that no oxidation takes place, when the pH of the medium is considerably less than 10.

It follows then, that the biological oxidation of the manganese in a medium of which the pH is considerably less than 10, must be possible. In order to show this, a culture plate was made of the following composition:

Dune water	100	cc.
Agar	2.5	grams
$(NH_4)_2SO_4$	0.1	gram
KH_2PO_4	0.05	gram
$Mn(HCO_3)_2$	0.16	gram

For the formation of the feeding medium pure manganous carbonate was suspended in dune water, saturated with carbon dioxide and afterwards filtered. To a warm 2.5 per cent solution of agar in dune water, to which had previously been added the feeding salts and which

[12] F. P. Treadwell. Lehrbuch der analytischen Chemie, II Bd., 1907, p. 96.

was cooled so far, that it was just liquid, so much of the manganous bicarbonate solution was added, that the plate contained 0.05 per cent Mn = 0.16 per cent manganous bicarbonate, in which one may succeed after some practise and without making the culture plate too soft. The quantity of manganese is to be determined by taking out a piece of the agar plate, dissolving this in water and determining the manganese colorimetrically. So in 6 cc. was found 3.01 mgm. Mn, which agrees with a quantity of 0.05 per cent in the culture plate. Using less than this quantity of manganese, the brown coloring of the manganese bacteria colonies may be no longer prominent.

After coagulation of the agar the surface of the plate is carefully dried at about 40°C. Then manganese microbes from the raw water or from the mud of the rapid filters are streaked off on the plate, to be cultivated at 25°C.

In order to examine the exact degree of acidity of the feeding medium, a cylinder of agar was cut out with a corkdrill and the empty space filled up with a solution of blue litmus (obtained by dissolving litmus in thoroughly boiled distilled water), after which the opening was closed with a glass cover in order to prevent the solution from slipping away, when the culture box is held in a vertical position. If now one holds the plate against the light, it is easy to judge the change of color of the litmus. After six hours another cylindrical hole is made in the same way, next to the first one, and filled with the same solution of the litmus. Holding the plate against the light we see that the first litmus cylinder has taken a violet color, whereas the second remains blue.

The difference in color is more or less evident according to the thickness of the layer of agar. The violet color of the litmus solution agrees with a pH of 4 to 5, which produces an acid reaction of the culture plate. After eight days of cultivation, during which the culture dish had been lying upside down in the incubator to prevent the agar layer from drying too quickly, slight brown colonies of manganese bacteria were to be seen in the inoculation streaks on the plate at a fifty-fold magnification. After fully 6 weeks brown spots in the inoculation streaks were visible to the naked eye, consisting of manganic peroxide, as the examination described above proves, while the plate, by repeating the test with the litmus-solution, still gave a decided acid reaction.

This cultivation test showed that the manganese bacteria can develop on a faintly acid medium of manganous bicarbonate. Their

successful growth on ordinary manganous carbonate plates, which gave a slight alkaline reaction by adding calcium acetate and dipotassium phosphate and their capacity of multiplication in the water of rapid filters (pH = 8.1) indeed proves, that their growth is improved by an alkaline reaction of the medium.

Besides being capable of oxidizing dissolved manganese at an alkaline degree, pH = 10, while the oxygen of the air is still inactive, the manganese bacteria can just as well oxidize in an acid medium of a pH 4 to 5, this being explained by the general acceptation that the protoplasm of the living cell reacts alkaline.[13] The oxidation of the manganese into manganic peroxide is supposed to happen in contact with the living protoplasm of the microbe, cell a supposition already made by M. W. Beijerinck[14] when he stated: "dass die Oxydation sicher an die Substanz des Bakterienkörpers gebunden ist."

Using a strong magnification a small quantity of the brown material of the colonies appears to consist of very small light or dark brown lumps. In the lighter ones small micrococci and also short bacteria rods of 0.6 μ thick are visible. When the diaphragm is widely opened, one can distinctly see that the contents of the greater part of cocci and bacteria is brown yellow to brown. As this seems to support the view that the oxidation of the manganese into manganic peroxide in the bacterium cell is promoted by the living protoplasm, in the fungus culture mentioned before, yet lumps of manganic peroxide are to be found outside the mycelium. M. W. Beijerinck[15] also observed that in the fungus Papulospora manganica, manganic peroxide-spheriods lie at a rather great distance from the mycelium threads. No oxidizing matter, diffusing from the mycelium was to be found. Besides, he observed, that there is no question here of an alkaline reaction of the culture plate by the fungus growth. Therefore, he pointed out, there is still but little known about the real mechanism of the oxidation process.

J. Tillmans[16] explains the oxidation of dissolved manganese in slightly acidly reacting water, which cannot be produced by the oxygen of the air, by presupposing that the materials of the filter, such as cokes, stones, sand, etc., can contain alkaline reacting mate-

[13] H. Molish. Mikrochemie der Pflanze, 1913, p. 23.
[14] Verzamelde geschriften, Dl. V, p. 143.
[15] Loc. cit., p. 145.
[16] Loc. cit. p. 720.

rials. In the proximity of these materials the water is supposed to possess a weak alklaine reaction by which manganous hydrate deposits more and more and the oxidation into manganese dioxide proceeds. This purely chemical point of view of Tillmans is not tenable, as first and foremost the influence of the alkaline reacting materials in the water would have to be indicated by the determination of the hydrogen exponent, which has not been proved. We have already found that, even in weakly alkaline reacting water of a pH between 7 and 10, the oxygen of the air by no means produces a manganese oxidation. Secondly, the filling material of the filter comes to a point of being lixiviated, so that a gradual decline should take place in the oxidation of the manganese, which does not occur. Apart from the biological manganese removal from the water, according to Vollmar[17] in Dresden, Tillmans[18] leaves open the possibility that microörganisms coöperate in the oxidation process of the manganese, but this biological oxidation, according to Tillmans, only takes a subordinate place.

It is more rational to replace the chemical explanation of the manganese oxidation by the biochemical point of view, because this quite agrees with the facts.

MANGANESE DIOXIDE RETAINS MANGANOUS COMPOUNDS

A well known property of manganic dioxide is the capacity to retain manganese as manganous compounds from their watery solutions. In many methods of purifying water, one has made use of this knowledge in order to remove manganese from raw water.

As before shown, the manganese bacteria are able to oxidize manganous compounds into manganic dioxide, both in weak acid and weak alkaline solutions, which in its turn absorbs manganous compounds from the water.

Therefore the manganese microbes do not only promote the regeneration of the capacity of manganic dioxide to retain once more manganous compounds by oxidizing them, but they add newly formed manganic dioxide, so that in a normally working rapid filter the manganese removal from raw water can take place without interruption.

When the experimental plant of the rapid filters at Leiduin was

[17] Journal für Gasbeleuchtung und Wasserversorgung, LVII Jahrgang, No. 29, p. 723.

[18] Loc. cit., p. 721.

placed in use in 1907, the filter basins were filled with ordinary new gravel. In the course of time the color of the gravel turned into dark-brown, chiefly by the deposition of manganic dioxide and ferric oxide on the pebbles. In connection with the high quantity of manganic dioxide, which the pebbles retain, one is inclined to think that the filling mass of the filter plays a part in the deposition of manganic dioxide on the pebbles, which by examination proved true.

FRESH GRAVEL RETAINS MANGANOUS COMPOUNDS THE SAME AS MANGANIC DIOXIDE

It soon appeared to me that manganic dioxide was not the only material which retains manganous compounds, e.g. carbon, calcium carbonate and also fresh gravel have the same capacity. This may be shown, by shaking these materials with much diluted manganous solution, which caused the quantity of manganese to decrease. The compound retained by the fresh gravel in a rapid filter is manganese, that indeed appears in solution in raw water, while the everpresent manganese microbes on the surface of the pebbles oxidize the retained manganese into manganic dioxide. The very thin layer of manganic dioxide thus formed retains in its turn dissolved manganese from the surrounding water, which is again oxidized into manganic dioxide. By this uninterrupted and alternating process of retaining and oxidation of the manganese, the manganic dioxide layer grows thicker and thicker, so that in the end it is covered with a dark brown layer. Of course, the thickness of it will be limited, because the layer is worn away by the continually flowing water; especially when the filter is cleaned the gravel is brought in a state of commotion by which the layer gets partly rubbed off from the gravel. The deposition of the mud in the rapid filter contains therefore manganic dioxide.

THE REGENERATION OF MANGANIC DIOXIDE, WHICH IS ALREADY PRESENT, AND THE FORMATION OF FRESH MANGANIC DIOXIDE

Though several materials appear capable of retaining manganese, this quality is particularly important for manganic dioxide, for the following reasons:

1. The regeneration of manganic dioxide, already present, is caused by the oxidation of the retained manganous compounds, which again enables it to retain once more manganous compounds.

2. The oxidation just mentioned continually causes a new formation of manganic dioxide, which, combined with the former quantity

of manganic dioxide, retains ever more manganous compounds. The process of microbiological manganese oxidation leads therefore naturally to the removal of manganese by means of manganic dioxide.

EXPLANATION OF THE PHENOMENA IN THE REMOVAL OF MANGANESE FROM RAW DUNE WATER BY NEW RAPID FILTERS

We have already proved that fresh gravel is capable of retaining dissolved manganese. But the cement walls of the rapid filters, containing calcium carbonate, can as well operate in retaining manganese. The small quantity of manganic dioxide, suspended in the raw water, is able to do this. This manganic dioxide, however small in quantity at first, slowly increases in the working filter and also joins in the absorbing of the dissolved manganese, after the continual regeneration. The same process of the formation of a brown layer over the pebbles takes place also in new rapid filters. Within a few years the gravel turns dark brown.

THE REMOVAL OF THE MANGANESE FROM RAW DUNE WATER BY SANDFILTERS.

When feeding the sandfilters with raw dune water, one is inclined to expect that the sand, like the gravel of the rapid filters, in the course of years would have turned dark brown by the manganese deposition, because the filtered water contains no manganese. By superficial observation however no brown coloring is to be noticed. But when a hole is dug in the sandbed, brown veins are visible in the profile, containing manganic dioxide. In a sandfilter fed with raw water, a process takes place in the sandbed analogous to the process going on in the fresh mass of gravel of a rapid filter. Sand and calcium carbonate which is also present, retain manganese, that is changed into manganic dioxide by oxidation. Gradually there is formed a sufficient quantity of manganic dioxide, by which chiefly manganese from the water is absorbed.

The mass of gravel under the sandfilter also contains brown colored pebbles which color is caused also by manganese dioxide. All this shows that the oxidation of the manganese in a sandfilter takes place throughout the whole depth of the sand and gravel layers of the filter.

THE REASON THE SANDFILTERS ARE NOT CONSPICUOUSLY COLORED BROWN BY THE SETTLED MANGANIC DIOXIDE

Four reasons may be mentioned, which combined explain why the settlement of manganic dioxide does not considerably color the sand of the sandfilters brown, that some years before for a long time were fed with raw water, as it is the case with the gravel of the rapid filters.

1. The periodic removal of the uppermost filter layer, when cleaning the filter, by which a part of the deposited manganic dioxide is also removed.

2. The relatively small quantity of manganese in the raw water amounting to an average of 0.3 mgm. per liter.

3. The low rate of the water passing through the sand bed, being about 10 times slower than in a rapid filter, so that in the same unit of time a quantity of water 10 times smaller comes into touch with a constant quantity of filter material.

4. The whole surface of the sand grains, which is considerably larger than that of the pebbles of gravel in the rapid filter.

THE DISCARDING OF MANGANESE FROM RAPID AND SANDFILTERS TAKES PLACE IN THE SAME WAY

It is evident that the settled manganic dioxide in the sandfilters is formed by manganese microbes, which may be concluded by analogy with the formation of manganic dioxide in the rapid filters. Therefore, the oxidation and removal of the manganese takes place in the same way in both kinds of filters. We do not find any essential difference, but only a gradual one.

In the preceding examination of the processes, going on in the removal of manganese from potable water, only a few questions were answered which form a whole. The manner in which the manganic dioxide retains manganous compounds and by what law it is governed still remain unexplained.

SUMMARY AND CONCLUSIONS

1. While the complete removal of the manganese dissolved in raw dune water takes place in the rapid filters by oxidation into insoluble oxide, by the same process a part of the manganese settles in the open shallow canals of the drainage area. The sulfate reduction generally appearing here probably is one of the causes, why the water does not reach the purifying station free from dissolved manganese.

2. By means of the iodometric and oxidimetric titration methods the deposition of manganese, both in the rapid and in the sandfilters as well as in the mud of the canals, is demonstrated to take the form of manganic dioxide.

3. Manganese microbes appear in raw dune water, which, when cultivated on suitable culture plates, show the capacity to oxidize manganous salts into manganic dioxide.

4. The hydrogen exponent of raw dune water proves to be too low to enable the auto-oxidation of the dissolved manganese. However, the oxidation does take place, due to the ever-present manganese bacteria, which possess the capacity to oxidize manganous salts into manganic dioxide.

5. Fresh gravel has, as manganic dioxide, the same property of retaining dissolved manganous combinations from water. By oxidation, influenced by the manganese microbes, manganic dioxide arises from the manganous compounds, by which the gravel is covered. This thin manganic dioxide layer likewise retains dissolved manganese from the water, which again is oxidized into manganic dioxide. This oxidation causes the manganic oxide already formed to be once more capable of retaining manganous compounds. By this process of regeneration, which at the same time causes the formation of new manganic dioxide, the retention and oxidation of manganous compounds can proceed uninterruptedly. It is characteristic in this process that just manganic dioxide is formed by the oxidation of manganese, which by itself is capable of absorbing dissolved manganese from the water.

6. The removal of manganese in sandfilters, which formerly were with raw dune water, took place exactly in the same way as in the rapid filters. The materials, which at first retained the dissolved manganese, were sand, calcium carbonate and coarse gravel.

7. The whole investigation led to the conclusion, that in the removal of manganese at the waterworks at Leiduin, the bacteria play an essential part.

DISCUSSION

Robert Spurr Weston: The author of this paper has greatly contributed to the fund of information regarding the oxidation of manganese in ground waters. Especially interesting are his methods for determining manganese in its various degrees of oxidation, in

filter beds, pipe deposits, and basin sludges, and his experiments to prove that in the oxidation of manganese the lower bacteria, rather than contact or the higher bacteria (Leptothrix and others of the family), play the important rôle.

The author's experiments indicate that direct oxidation of manganese, as by bubbling air through a manganiferous water, takes place only in highly alkaline waters (pH equals 10) and he ascribes to the manganese bacteria, rather than to catalysis by physical contact, the chief part in oxidation.

It is a little difficult to understand the author's statement that "anäerobic and äerobic conditions occur in the same water at the same time" unless he means conditions like those which occur in deep lakes and ponds. In these waters, reduction may take place in the stagnant zone, while oxidation may be going on in the circulating zone. The same would be true in the lower and upper zones of canals, respectively. Perhaps he means two kinds of water and bacteria in the same body of water, rather than two kinds of active bacteria in the same water.

Sand or gravel filters treating waters containing iron and manganese frequently show distinct zones of discolorization, the upper colored red with iron, the lower brown with manganese.

In the material adhering to the Amsterdam filters, there was 33 per cent of manganese and 28 per cent of organic matter. Manganese found in deposits at Brookline and Newton, Mass., had the compositions given in table 1.

The waters from which these deposits were derived had the characteristics shown in table 2.

It is difficult to go quite so far as the author in giving manganese bacteria sole credit for the oxidation of manganese salts. All will agree that in waters whose pH values range from say 7.5 to 8.5, the accumulated manganic hydrate on the filter sands adsorbs and holds the unoxidized manganese until it becomes slowly oxidized and until the accumulation becomes so great that it sloughs away. However, the author's conclusion regarding bacteria is quite a step away from the older idea of Dunbar and others that bacteria constitute surface, and surface increases adsorption and promotes oxidation by physicochemical action rather than by biolysis. The author's quotation from Beijerink regarding the relatively great distance separating the aggregates of manganese oxide and the body of *Papulospora mangan-*

TABLE 1

Manganese in Deposits, Brookline, Mass.

	TRICKLER DEPOSIT	SEDIMENT FROM TRICKLER EFFLUENT	SEDIMENT FROM FORCE MAIN
	per cent	*per cent*	*per cent*
Silica, SiO_2	19.06	45.29	5.03
Iron oxide, Fe_2O_3	16.84	34.68	16.40
Aluminum oxide, Al_2O_3	0.64	1.20	1.22
Manganic oxide, Mn_3O_4	15.70	3.01	51.95
Calcium oxide, CaO	2.67	0.87	4.24
Loss on ignition	40.44	10.82	17.86

Newton, Mass., Deposit in Wooden Conduit

	NO. 1—NEXT TO WALL	NO. 2—NEXT TO WATER
Silica, SiO_2	7.25	5.4
Iron and aluminum oxides	10.2	85.4
Manganese dioxide	70.+	Trace
Loss on ignition	11.9	4.75

TABLE 2

DETERMINATION	BROOKLINE, WELLS AND GALLERY	NEWTON, WELL AND WOODEN CONDUIT
	p.p.m.	*p.p.m.*
Oxygen consumed	2.05	1.5
Iron, Fe	0.85	0.20
Manganese, Mn	0.20	0.25
Nitrogen as free ammonia	0.040	0.044
Nitrogen as albuminoid ammonia	0.090	0.130
Nitrogen as nitrites	0.000	0.000
Nitrogen as nitrates	0.30	0.12
Hardness	50.0	31.2
Alkalinity	39.0	23.0
Chlorine	8.4	10.0
Residue on evaporation	108.0	80.0
Carbon dioxide	31.8	15.0
pH value		6.5

ica, and also Schwer's[19] experiments at Turnhout, Belgium support Tillman's belief that the rôle of the higher iron bacteria is at least a secondary one. The author's experiments have certainly introduced another group of organisms, and show either that they are the chief oxidizing agents for manganese, or that, when grown in solutions containing manganese and oxygen, manganese salts become a part of their cell substances.

It is a little difficult to imagine that the laws of oxidation apply differently in the case of waters containing manganese than they do in the case of waters containing iron. At Reading, Mass.[20] the writer found that the oxidation of iron failed when water was aerated to such a point that Leptothrix ochraceae would not grow in a trickling filter, and at Lowell Barbour found that manganese could not be removed with iron when aeration was carried so far that the carbon dioxide was reduced to the practicable low limit. These facts do not seem to disprove chemical oxidation of waters having a pH value of less than 10, where the surface area of the precipitated iron in contact with the water under treatment is large.

It must be borne in mind that the time element in the author's experiments on direct oxidation was small compared with that obtaining in a well-ripened filter in practice.

The point is an interesting one, and the writer must now believe that both contact and bacteria are effective agents both for the removal of iron and the removal of manganese, otherwise one could not explain certain stains, due to manganese, on walls and plumbing fixtures where the alkalinity is not high, and where it seems that it would be difficult for oxidizing bacteria to thrive.

JOHN R. BAYLIS: This excellent article is a valuable contribution to the literature on manganese in water supplies. Troubles from such source are more extended than is generally believed, and the article is not only interesting to those handling water containing manganese, but to every one interested in water treatment. As stated by the author, it has been known that biological growths play an important part in the precipitation and resolution of manganese, but it was not known that the precipitation of manganese, except where special chemical treatment is given, is due almost entirely to certain biological growths. One wonders what would happen if the

[19] Revue'd'Hygiene, xxx, 297, 1908.

[20] Trans. Amer. Soc. C. E., xliv, 151.

water was treated with chlorine to the extent of preventing such growths. It is possible, however, that the presence of an excess of chlorine will cause oxidation of the manganese where it otherwise would not be except by biological growths.

During the first serious manganese occurrence in the Baltimore water supply in 1923, the writer conducted a number of experiments on various means of removing the manganese. In this case biological growths apparently were responsible for the resolution of manganese already precipitated on the bottom of a large storage reservoir and along the walls of a tunnel over 7 miles in length. Part of this work has been published.[21] It was the writer's intention to publish another article giving additional facts brought out by the investigation during subsequent manganese occurrences, but time for writing the article has not been available. Looking over the notes, there seems to be agreement with Kühr's work in so far as the experiments overlap, except in one or two minor points.

It was found that the ortho-tolidin solution used for making residual chlorine tests is the most sensitive test for oxides of manganese containing more oxygen than manganous oxide. This test is sensitive to less than 0.1 part per million of manganese (Mm) existing as manganese dioxide. The addition of an alkali to the Baltimore water containing approximately 1 part per million of manganese gave a slight yellow color when the water was at a pH of 8.0 before the addition of the ortho-tolidin. The color increased as the pH was increased. This, or course, applies to the pH of the water before the addition of the ortho-tolidin.

One might come to the conclusion by reading the article that manganese is not adsorbed by and precipitated with the hydrous oxides of iron. This may be the case when the pH is below 7.0, but when the water is slightly alkaline the amount of manganese occurring ordinarily in water supplies is readily precipitated with the iron. The iron and lime treatment appears to be the most effective means of removing manganese from water. This has been tried out thoroughly at Baltimore, not only in the laboratory but also in the filter plant. One part per million of manganese (Mn) is easily removed with 15 to 20 parts per million of ferrous sulfate ($FeSO_4$, $7H_2O$) and enough lime to give the water a pH of about 8.8 or more alkaline.

The pH of the water apparently has some influence on the removal

[21] Baylis, John R.: Manganese in Baltimore Water Supply. This Journal, vol. 12, no. 2, 211, October, 1924.

of manganese, for one-half of the water at the Baltimore filter plant was treated with lime to a pH of from 8.5 to 9.0 before filtration, in an experiment extending over several weeks, and the filter beds having the alkaline water removed more of the manganese than did the other filters. The water going on to one filter was dosed highly with chlorine for a period of several weeks during one of the manganese occurrences and while this bed showed a better adsorption than did the others the amount removed from the water was still less than 50 per cent of the amount going on to the bed. Draining the filter dry and allowing it to stand in contact with the air for a few hours increased the adsorption about the same as such a procedure did in the beds where no chlorine was added.

Manganese can be removed very easily by chemical treatment of the water, but the writer agrees with Kühr that biological growths play by far the most important part in the oxidation of manganese in most instances. The presence of dissolved oxygen in the water apparently will not cause rapid oxidation of manganous hydroxide when the pH is below about 8.0 or perhaps slightly higher, but there is probably a very slow oxidation below this point which is not rapid enough to cause very much precipitation or adsorption of manganese. Any one troubled with manganese should read this article, for it is a thorough treatment of a subject that has received little attention in this country.

F. E. HALE: The paper on "Manganese in Water Works" by Kühr is a most interesting study from a biological standpoint. Of particular importance is the separation of cocci, bacilli and fungi and the description of method of culture. That bacteria and other organisms may utilize manganese in their life processes has been known for many years. In 1901 D. D. Jackson[22] published a paper from Mt. Prospect Laboratory describing a new species of Crenothrix, C. manganifera, which forms chains of bacteria imbedded in manganese oxide. In describing the three forms:

Crenothrix, kühniana, utilizing iron
Leptothrix, ochracea, utilizing aluminum (suggested name Crenothrix ochracea)
Crenothrix, manganifera, utilizing manganese

[22] Trans. Amer. Micro. Soc., Vol. 23, pp. 31–39; Jour. Soc. Chem. Ind., May 31, 1902, pp. 681–4.

Jackson states "All three species occur chiefly in ground waters and only grow with rapidity when the dissolved oxygen is lacking, or nearly so, and when the special salts are present which they precipitate. The presence of much organic matter seems to favor the growth, but the two former conditions are absolutely necessary. The absence of light and the presence of carbonic acid in the water are also usual conditions and seem to favor growth." Analyses of the precipitates showed iron, aluminum and manganese oxides predominating in the three respectively and in the waters in which they grew respectively. He also stated that "These salts of iron, aluminum or manganese, combined with organic matter, seem to furnish the food material for the organisms, while the oxides of iron, aluminum or manganese which are precipitated in their gelatinous sheaths are the dross of the operation."

The control of Crenothrix in distribution mains by chlorination either by liquid chlorine or chloramine was described by W. F. Monfort[23] in 1919 and was based on destruction of the Crenothrix bacteria. Monfort discussed briefly with several references the relation of iron to the life processes of Crenothrix. Similar relationship probably exists as to manganese.

Ellis[24] also has written of "Iron bacteria in relation to incrustation of pipes."

The importance of small amounts of manganese in stimulating plant growth has been recently emphasized by McHargue.[25] He states that manganese functions in the synthesis of chlorophyl and carbon assimilation, that manganese stimulates plant growth up to 10 parts per million and above that amount is toxic. Several references are included in this connection.

That the change of state of oxidation of manganese, however, is always entirely biological does not seem plausible, despite the careful chemical experiments and regulation of pH by Kühr, since manganese is a well known carrier of oxygen, or a catalyzer. Living organisms merely utilize this characteristic property. In elementary chemistry it is a common experiment to mix manganese dioxide and potassium chlorate and to heat gently in a retort to produce a quiet stream of oxygen. Without the manganese dioxide there would likely be an

[23] This Journal, vol. 6, June, 1919, pp. 196–201; Proc. Ind. San. W. S. Assoc., convention April 9, 1919.

[24] Engineering, vol. 112, 1921, pp. 457–8; Chem. Abs., vol. 16, 1922, p. 601.

[25] Jour. Ind. Eng. Chem., vol. 18, February, 1926, p. 172.

explosion as the chlorate disintegrated, but in the presence of manganese dioxide the chlorate reduces quietly to chloride. The manganese probably passes through many changes of state of oxidation, although in the final product the manganese remains as dioxide. In the paragraph before his summary Kühr admits that "The manner in which the manganic dioxide retains manganous compounds and by what law it is governed still remain unexplained." It seems likely that manganese dioxide, MnO_2, combines by chemical action with manganous oxide, MnO, to form manganese trioxide, Mn_3O_4, which then is oxidized to the dioxide by either chemical or biological action.

Chlorine will readily oxidize manganous salts in natural waters to manganese dioxide and in these instances the pH is well under 10. Well waters containing manganese when chlorinated with gaseous chlorine will coat the glass syphon measuring tubes of Wallace and Tiernan machines so black that one cannot see through them.

On the other hand, somewhat in agreement with Kühr's work, Weston[26] ascribed greater difficulty of oxidation in removal plants to manganese than to iron. At the water works convention in 1921, he stated "Much less carbonic acid is required to prevent precipitation of manganese than of iron, and in one case it was possible to completely remove the iron and leave the manganese in practically permanent solution simply by stopping the aeration at the proper point."

That bacteria aid many obscure reactions, is, however, known in many instances and surmised in others and the above work is a decided addition to our specific knowledge. Similar conditions probably exist in iron removal plants and variation in bacterial content may explain the ease or difficulty that is experienced in accomplishing the complete removal of iron. Hale[27] in describing iron removal called attention to the fact that efficiency increased as the sand became coated with iron oxide and "ripened." This statement was questioned at that time by Milliken of the then well known New York Jewell Continental Filtration Company.

Manganese is more prevalent in water supply probably than has generally been suspected. It is contained frequently in clay and in water usually whenever iron is present to any extent, and probably comes from decaying leaves or vegetation. The difficulties caused

[26] This Journal, vol. 9, May, 1922, p. 492.

[27] This Journal, vol. 3, March, 1916, pp. 123–141.

by it in this country have been described several times recently. Baylis in 1924 also discussed the biological side of the question. The following are a few additional American references:

KNEELAND, H. C.: Manganese in laundry and pipe lines. This Journal, Vol. 13, April, 1925, p. 436.

CORSON, H. P.: Manganese in water supply. Uni. Ill. Bull. W. S. Series 13, 1916, pp. 144–204.

APPELBAUM, S. B.: Manganese in ground water and its removal. Jour. Ind. Eng. Chem., Vol. 8, February, 1916, p. 160.

HALE, F. E.: Experience with manganese in the Croton water of New York City. Read at convention at Buffalo, New York, June, 1926. This Journal, (in press).

A PROGRAM FOR PROTECTING CHICAGO'S LAND TUNNEL SYSTEM[1]

By H. H. Gerstein[2] and Arthur E. Gorman[3]

During the last two years extensive investigations have been made in Chicago of the water tunnel system to locate possible sources of pollution, especially by leakage from sewers into adjacent shafts. This work was prompted by a marked difference in the bacterial quality of water samples collected from intakes at the lake cribs and those from intermediate points in tunnels between the lake intakes and the pumping stations served. As the result of studies made since 1924 a program for protecting water tunnel shafts has been adopted, the development of which will be presented in this paper.

In order to distribute water from its six intakes in Lake Michigan to the ten pumping stations, the City of Chicago has in operation about 58 miles of tunnels, 22 miles of which are under the lake and 36 miles under the city. A detailed description of these tunnels and the connecting land shafts was given by one of the authors in a paper in The Journal, Vol. 14, page 175, entitled "Experiences with Large Land Tunnels in Chicago" and, therefore, will not be repeated here

Unlike tunnels serving most of the large cities of this country those in Chicago are not under pressure. This fact, together with the loss of head resulting from flow through the tunnel, presents unusual complications which make the protection of the tunnel system against pollution from surface sources, and in particular from adjacent sewers, a serious problem.

In any level district the depth to which sewers and underdrains are laid usually determines the ground water level due to infiltration. In Chicago the ground water level in the vicinity of a tunnel shaft may dip to approximately the elevation of the water in the shaft, which is usually many feet lower than the adjacent sewers. Figure 1

[1] Presented before the Iowa Section meeting, November 3, 1926.

[2] Assistant Sanitary Engineer, Division of Water Safety Control, Bureau of Engineering, Chicago, Ill.

[3] Chief Sanitary Engineer, Division of Water Safety Control, Bureau of Engineering, Chicago, Ill.

illustrates the simple hydraulics involved in Chicago's tunnel pollution problem. Obviously the situation is dangerous when a sewer is located within a few feet or yards of a tunnel shaft. In any sewerage system there is liable to be more or less leakage from the joints in the sewers or the connecting house drains, especially when

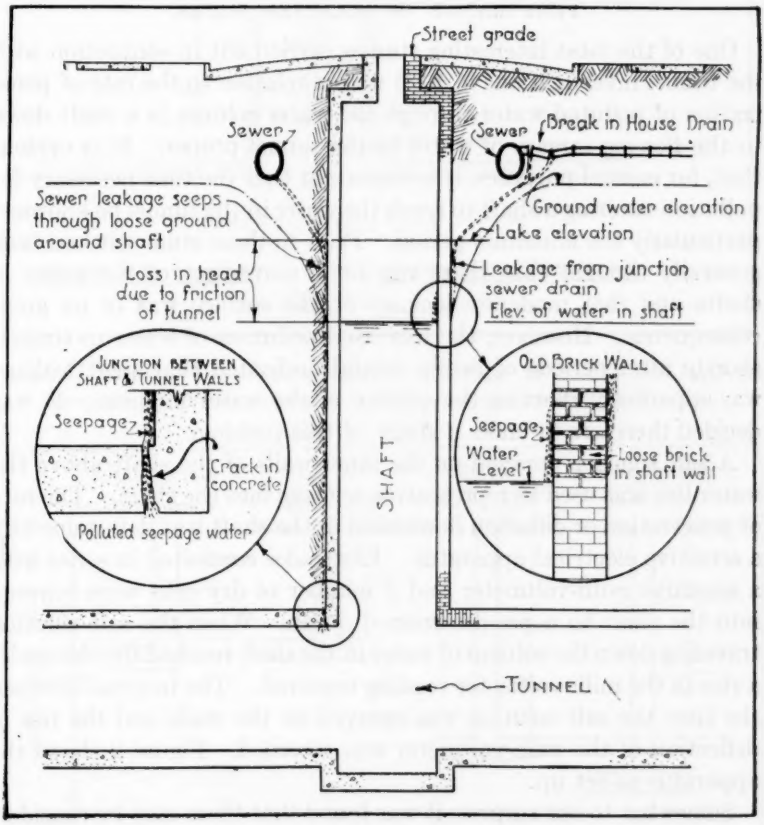

FIG. 1. SCHEMATIC DIAGRAM SHOWING MEANS OF ENTRANCE OF SEWAGE POLLUTED GROUND WATER INTO TUNNELS AND SHAFTS

the sewers are overtaxed as in Chicago. Under these conditions the leaking sewage will follow the flow of ground water and may enter the shaft. This combination of sewers adjacent to water tunnel shafts and a sewerage system generally undersize and subject to serious flooding, even after rains of only moderate intensity, consti-

tutes a serious potential hazard to Chicago's water supply. Considering the possibilities for leakage it is indeed fortunate that more leakage has not been experienced. This is considered due to the impervious clay which surrounds many of the larger sewers in Chicago and to the filtering effect of sandy sub-strata.

PENETRATION OF POLLUTED WATER

One of the most interesting studies carried out in connection with the tunnel investigations in 1925 was in relation to the rate of penetration of polluted water through the water column in a shaft down to the flowing stream of water in the tunnel proper. It is evident that, for control purposes, it is important that the time necessary for pollution entering a shaft to reach the water in the tunnel be known—particularly the minimum period. Prior to these studies it had been generally thought that there was little movement of the water in shafts and that moderate leakage at the surface was of no great consequence. However, the increased pollution of water in tunnels shortly after periods of heavy rainfall indicated that shaft leakage was apparently affecting the quality of the water in them. It was decided therefore to make a study of this problem.

A salt solution sprayed on the inner walls of the shaft above the water line was used as representing seepage into the shaft. The rate of penetration or diffusion downward in the shaft was determined by a sensitive electrical apparatus. Electrodes connected in series with a sensitive milli-voltmeter and a number of dry cells were lowered into the shaft to a pre-determined depth. When the salt solution traveling down the column of water in the shaft reached the electrodes a rise in the milli-voltmeter reading occurred. The interval between the time the salt solution was sprayed on the walls and the rise in deflection of the milli-voltmeter was recorded. Figure 2 shows the apparatus as set up.

Somewhat to our surprise it was found that there may be considerable movement of the water in a shaft overlying a tunnel, depending upon the depth of the shaft and the velocity of flow of the main stream of water in the tunnel. Traverses of several different types of shafts were made, comparisons of which are shown in figure 3. The time required for the salt solution to reach the tunnel varied from 6 minutes for a 25-foot shaft, in which there was violent disturbance of the water, to 345 minutes for a 50-foot diffusion in a deep shaft with little disturbance of the overlying water. Between

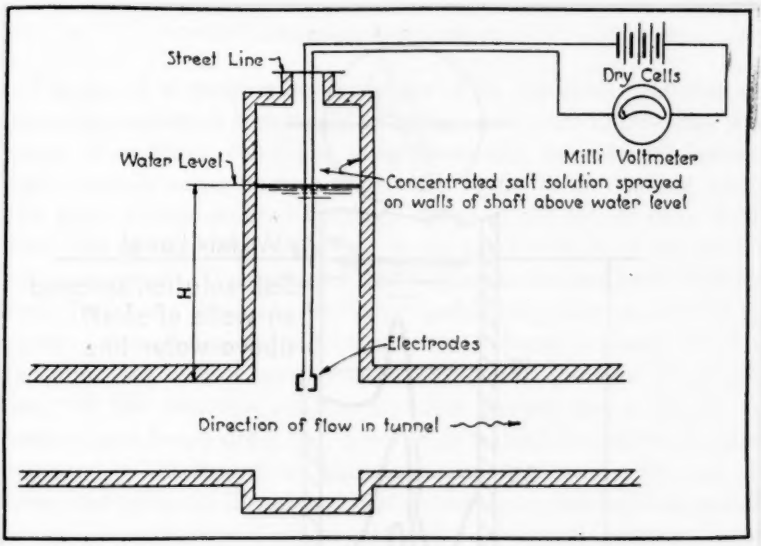

FIG. 2. APPARATUS USED TO DETERMINE THE TIME IT TAKES FOR SALT SOLUTIONS TO TRAVEL FROM WATER SURFACE IN SHAFT TO TUNNEL

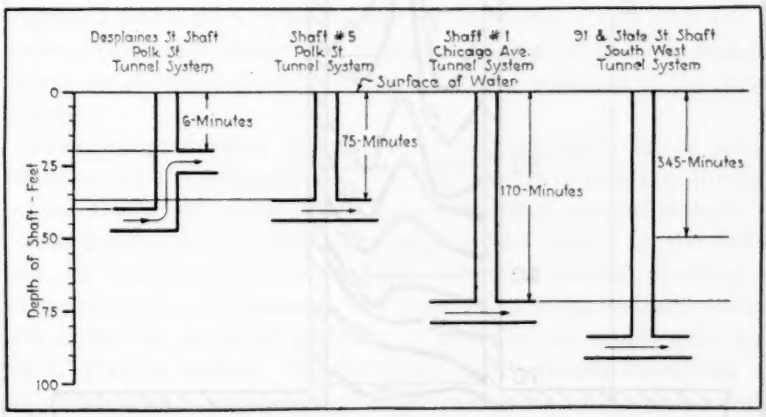

FIG. 3. TIME DETERMINED BY TESTS FOR SALT SOLUTION TO TRAVEL DOWN COLUMN OF WATER FROM SURFACE OF WATER IN SHAFT TO EYE OF TUNNEL IN VARIOUS TYPES OF SHAFTS

these extremes other periods were determined, but no general rule for prediction appears practical. A traverse of the Seneca Street shaft is shown in figure 4.

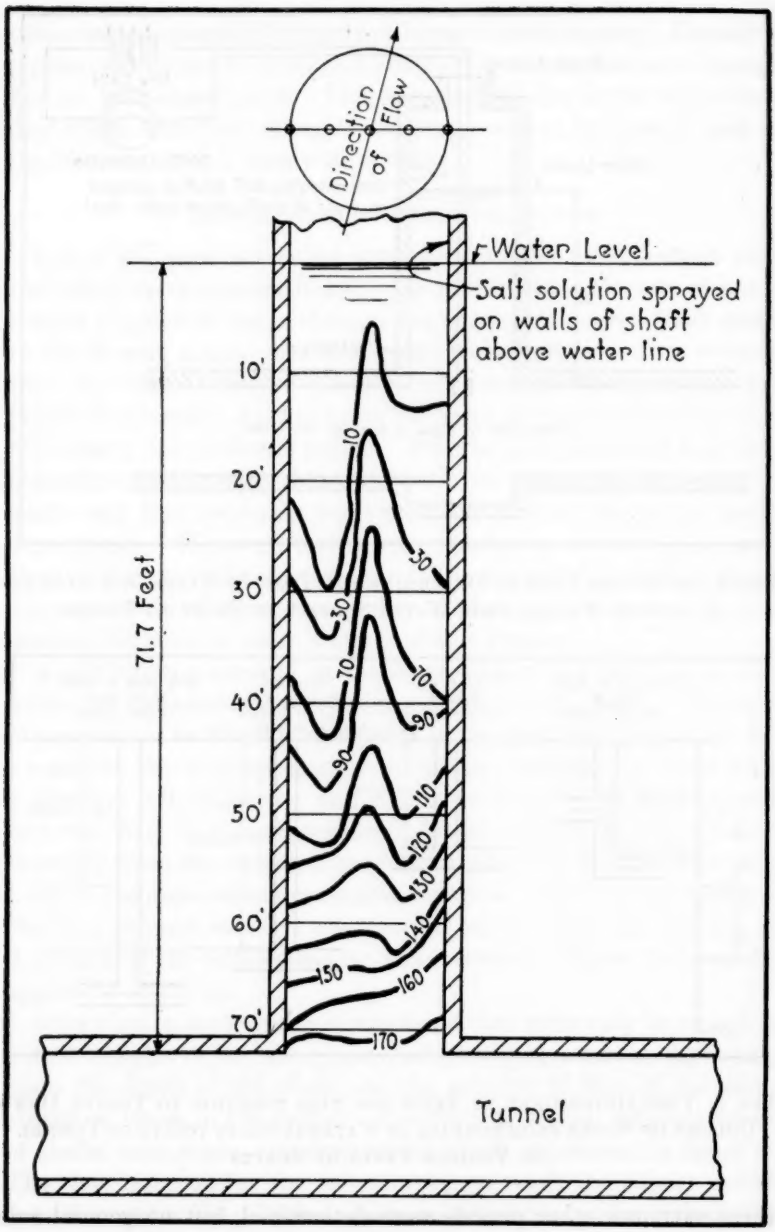

FIG. 4. CONTOURS SHOWING RATE OF PENETRATION OF SALT SOLUTION IN SHAFT NO. 1, CHICAGO AVENUE TUNNEL SYSTEM, AUGUST 24, 1923
Time in minutes

SEWAGE POLLUTION

The age of a sewer is no indication of its condition. During our investigations brick sewers laid some fifty years ago in blue clay were found in excellent condition with practically no outward leakage, while certain newer installations were found to be leaking badly. The most serious points of leakage noted in tile sewers were at the first joint in the house drain and in the lower portion of the joint in the main sewer. It is believed that in general the breaks in the house drain joints are due more to faulty back-filling than to careless tile laying. Some house drain connections were found seriously defective and indicated lack of competent supervision at the time of installation. If the drainage contractor, after having dug a trench for connecting a house drain to a sewer, fails to find the service junction indicated by the records he may even puncture a hole through the sewer and make an illegal and hasty connection, back-filling quickly so that his methods will not be detected. In several instances during the investigations of Chicago tunnel shafts, house drains were located passing directly over a back-filled shaft. Instances of house drains and sewers passing within a few feet of shaft walls are common. Figures 5 and 6 show typical cases. Conditions of this kind are, of course, positively dangerous and particularly so because leakage cannot be detected until indicated by actual pollution of the water supply.

From the standpoint of supervision over the safety of the public water supply in Chicago, these potential sources of pollution through tunnel shafts are really more dangerous than natural sources of contamination to the water surrounding the cribs. In the latter case, by studying such meteorologic factors as rainfall, direction of wind and barometric pressure, it is possible to predict within reasonable limits the degree of pollution of water at the intake cribs and the time of its arrival. On the other hand advance knowledge of pollution of the tunnel system through leakage into shafts is decidedly uncertain. Obviously, during and following periods of heavy rainfall, conditions are more or less dangerous and it is a general policy in Chicago to carry a higher dosage of chlorine in the water at these periods because of the uncertainty of tunnel pollution.

The route by which sewage polluted ground water may enter a tunnel shaft depends upon the type of construction of the shaft. Figure 1 illustrates the more common routes observed in the Chicago

investigations where both brick and concrete shafts and tunnels are used. The older brick shafts will readily permit the leakage of ground water. An excellent example is the leakage through the walls of shaft No. 10 of the 68th Street tunnel system. This brick

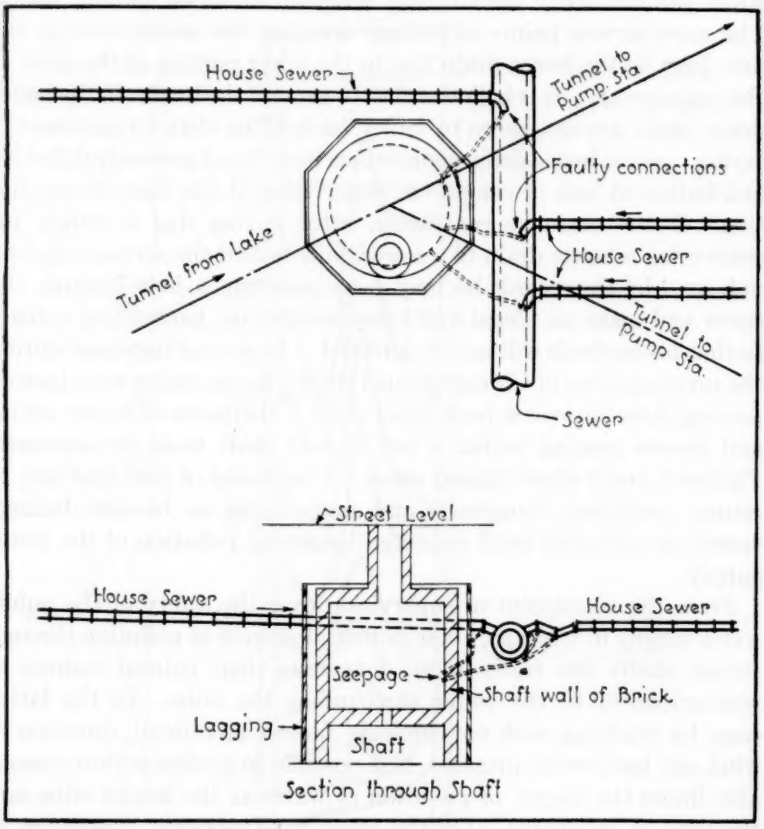

FIG. 5. POLLUTION OF GREEN STREET SHAFT BY LEAKING SEWER AND HOUSE DRAINS, 1924

shaft leaked ground water profusely. The entire inner wall, particularly below the water line, was found covered with a rust-colored gelatinous deposit varying in thickness from ½ to 3 inches. Under the microscope this material was found to contain innumerable filamentous organisms similar to crenothrix.

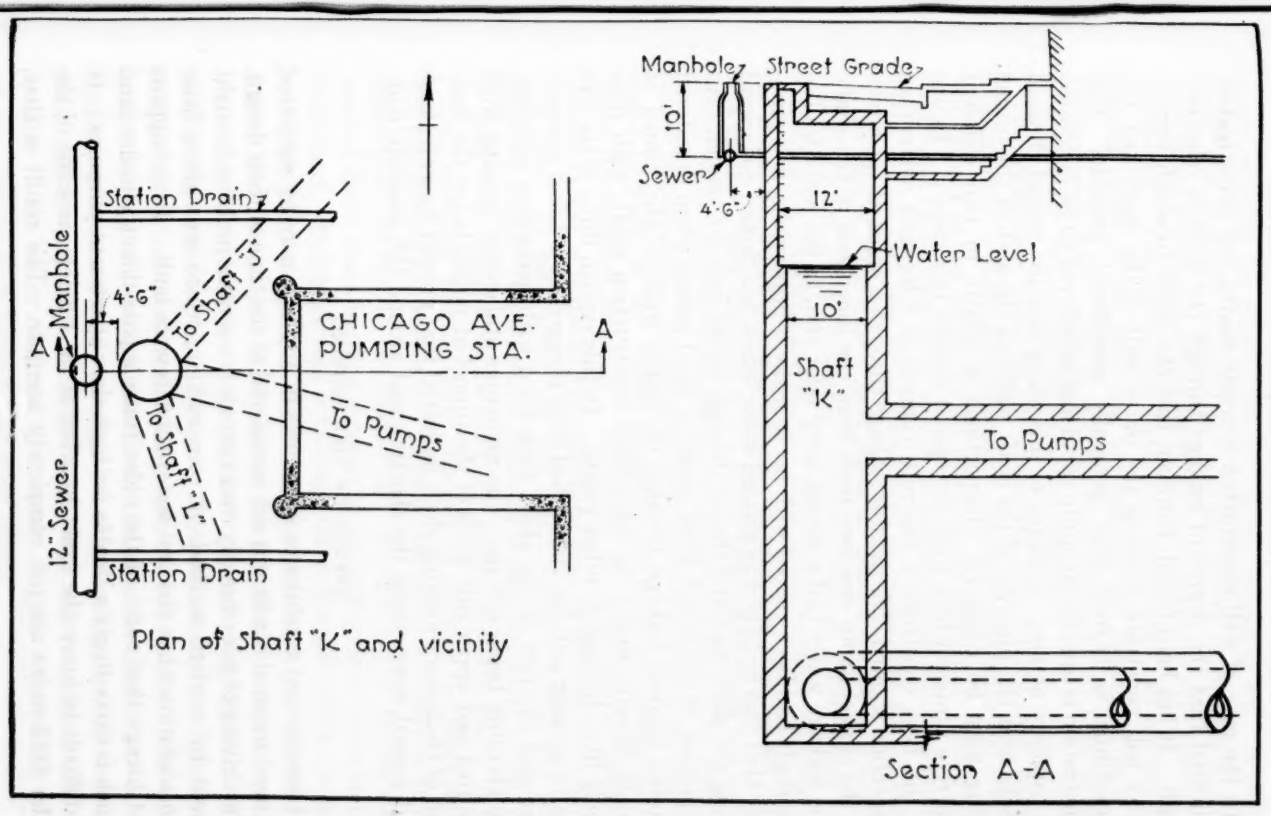

FIG. 6. DIAGRAM OF SHAFT "K" CHICAGO AVENUE PUMPING STATION SHOWING ADJACENT SEWERS

Note: When ends of sewer were blocked and the sewer flooded to a head of 10-feet evidences of leakage were seen inside shaft "K" above the water level.

LEAKAGE INTO CONCRETE SHAFTS AND TUNNELS

In the case of well constructed concrete shafts, our investigation indicated that the degree of leakage through the walls is relatively small. It has been found, however, that the depth to which surface water will penetrate between the outer wall of the shaft and the back-filling is beyond that generally considered possible. This penetration is apparently quite rapid and is believed to be facilitated by capillary action. Leakage of this water into the tunnel through cracks near the junction of the shaft wall and the arch of the tunnel lining may be expected. Inspections of shafts in two different concrete tunnels which were dewatered showed this clearly. In one of the best constructed concrete tunnels in Chicago's system an inspection showed considerable leakage through a crack at the crown of the tunnel about one foot back from the inner wall of the shaft. The leakage water had a strong tarry odor and, as the outer wall of the shaft had been coated with tar to make it impervious, it is probable that this leakage was ground water which had flowed downward along the shaft wall and thence through cracks into the tunnel. An inspection of the South Park concrete lined tunnel when dewatered showed marked leakage through the upper walls of the tunnel at points directly under the back-filled construction shaft, with relatively little leakage at other points. In this system three of the five shafts opening into the tunnel had been plugged by a 4-foot concrete core and the rest of the shaft back-filled with excavated material, the sheeting being left in. The numerous stalactites hanging from the roof and upper side walls of the tunnel at points below the location of the former working shaft indicated that ground water leakage had passed down along the sheeting and around the concrete core.

EFFECT OF PILE DRIVING

Underground conduits or structures in any city may be subjected to most unusual conditions not considered at the time of their design. The driving of piles directly over tunnels is a serious problem brought about by modern methods of construction, which was given little consideration when the first water tunnels were built. It so happens in Chicago that some of the older tunnels pass directly under land which is exceedingly valuable for high class apartment purposes. It is difficult to know the exact location of the tunnels, as some of the older field notes are not completely accurate. The result is that,

after laying out a system of piling so as to protect a tunnel, it is not known whether the piles as driven clear the tunnel or not. A policy which was recently adopted for the protection of tunnels against deep piling was to require at least ten feet clearance over the top of the tunnel. The contractors have complained that this reduces the bearing value of the piles and necessitates the placing of more of them. This is true, but it is considered necessary to hold to this policy for the protection of the tunnel system.

The vibrations following the impact of pile driving may have a serious effect in loosening the cement joints of terra cotta tile sewers. The impact of the driver on the pile may so affect well settled sub-strata and backfilling as to permit an unusual penetration of ground water. This fact was clearly indicated in connection with leakage in the fall of 1925 into a land shaft at Seneca Street in a branch tunnel to the Chicago avenue pumping station. This shaft was located in the parkway and had not been disturbed since constructed, the adjacent property being vacant. A sampling pump is set up in this shaft. Daily analysis of the water passing through the tunnel at this point had been made for almost a year and showed no unusual degree of pollution. However, as soon as the foundation contractors began to work on the vacant property the bacterial quality of the water deteriorated seriously. By means of steam shovels approximately 14 feet of material was excavated prior to driving the foundation piles. In excavating, the east side of the shaft wall was completely exposed. Water which collected in the excavation is believed to have been responsible for the early pollution of the water in the tunnel, probably due to lateral penetration through the shaft walls. The pile driving contractor was notified that no piles should be driven closer than ten feet to the shaft wall. As soon as the driving commenced there was a marked increase in the pollution of the water in the tunnel. In pile driving in Chicago where the sub-strata are sand and clay a jet method is used. In this process a jet of water is forced into the ground at the point the pile is to be driven, which effectively loosens the soil to a depth of approximately 30 feet. The pile is then inserted and driven. The preliminary jet introduces surface water to a considerable depth into the sub-strata. The subsequent driving of the piles effectively disturbs the deeper sub-strata and permits considerable penetration of ground water. It was not until pile driving in the vicinity of this shaft was completed that the quality of the water returned to normal. Figure 7 shows the effect of pile driving over tunnels and near shafts.

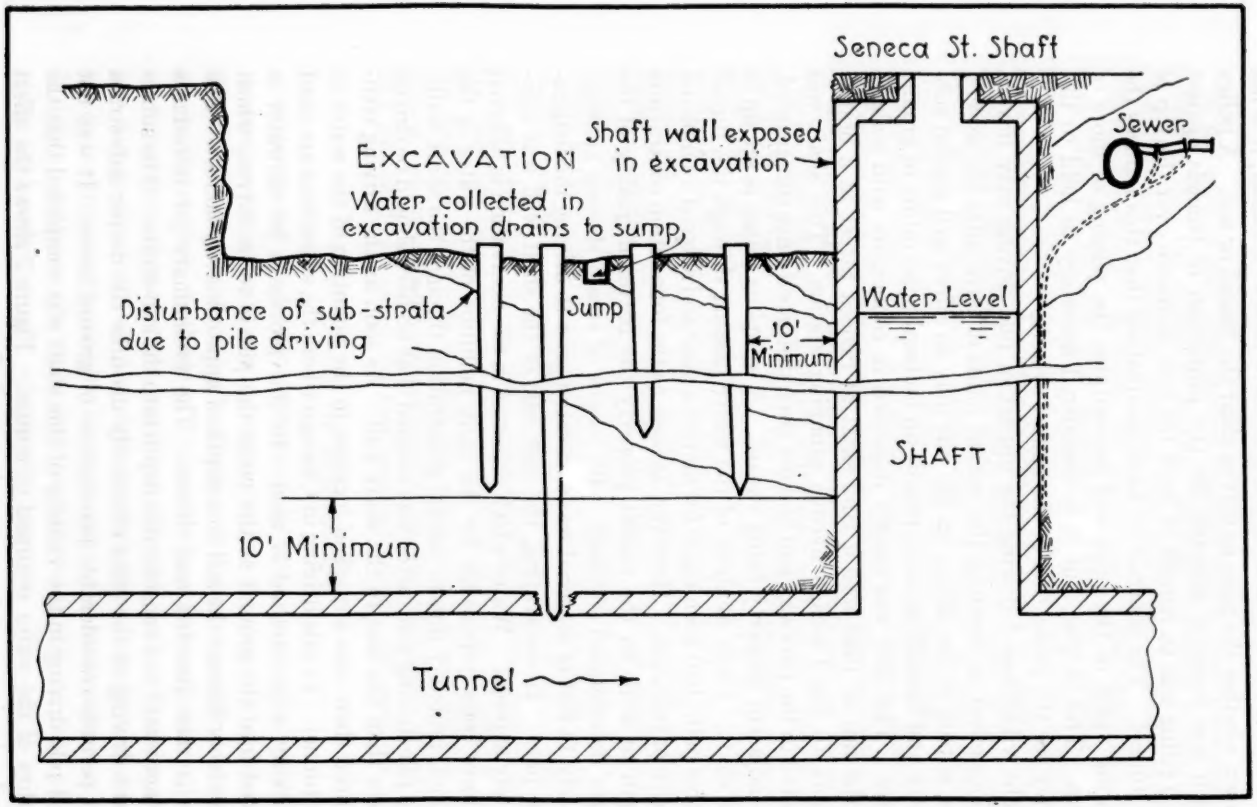

FIG. 7. DIAGRAM SHOWING PILING OVER TUNNEL AND NEAR SHAFT, ILLUSTRATING PENETRATION OF GROUND WATER THROUGH SUBSTRATA DISTURBED BY PILE DRIVING

PROTECTING TUNNEL SHAFTS

The Department of Public Works has adopted a general policy, with the recommendation of City Engineer John Ericson, which it is believed will be effective in protecting the tunnel shafts from leakage from sewers and house drains. This policy is to replace all sewers and house drains which are within 50 feet of tunnel shafts by cast iron water pipe with leaded joints. By carrying out this program the pollution by sewer leakage was effectively eliminated at the Green Street shaft and the suction well at the Harrison Street pumping station. In 1924 and 1925 investigations were made of the location and condition of all sewers in the vicinity of tunnel shafts, with the object of relaying them with cast iron pipe as soon as possible. Projects of this kind have been recently completed at the Lake View and 68th Street pumping stations, and work is now in progress at the Chicago Avenue pumping station.

Since Chicago's water supply program contemplates the use of land tunnels to deliver filtered water from filtration plants to pumping stations many miles inland, either by gravity or slight pressure, it may be readily realized that for public health reasons the protective program outlined must be continued.

THE ELECTROLYSIS SURVEY COMMITTEE OF BALTIMORE CITY

By H. Carl Wolf[1]

Officials of the Baltimore City Water Department early in 1922 requested the Public Service Commission of Maryland to take steps to organize a committee for the purpose of studying electrolysis conditions in the city and of mapping out a plan for improvement. Although the Commission was without direct authority in such a matter, nevertheless it asked representatives of those concerned with underground structures to meet and consider the problem. The Electrolysis Survey Committee of Baltimore City was subsequently formed, a representative was named by each of the following agencies, and the writer was elected chairman: Municipal Water Bureau, Municipal Electrical Commission, Municipal Police and Fire Alarm System, Consolidated Gas Electric Light and Power Company (Gas and Electric), Chesapeake and Potomac Telephone Company, American Telephone and Telegraph Company, United Railways and Electric Company, Washington, Baltimore and Annapolis Electric Railroad Company, Pennsylvania Water and Power Company, Baltimore and Ohio Railroad Company, Western Union Telegraph Company, Postal Telegraph Company, and Maryland Pipe Line Company.

The United Railways and Electric Company operates a 600-volt direct current rail return system with tracks covering pretty generally the streets in the city, and extending out into the suburbs in all directions. The Baltimore and Ohio Railroad Company has an electrified tunnel extending for one mile through the business section, and operated at 600 volts direct current. The Washington, Baltimore and Annapolis Electric Railroad Company has a short stretch of line in one section of the city operated at 600 volts d.c., changing to 1200 d.c. outside of the city limits, where it parallels gas and water mains for several miles. The Electric Company operates a 110–220 volt 3-wire d.c. net work in the business section. The electric,

[1] Chief Engineer, Maryland Public Service Commission, Baltimore, Md.

telephone, railway, and telegraph companies have extended systems of underground and overhead cables covering every section of the city, while the Water Power Company has certain transmission feeder cables through a portion of the city. The conduits, with the exception of those used by the telephone companies, are built and maintained by the city through the agency of its Electrical Commission. This system is being rapidly extended and as conduits are built, all overhead wires on streets must be removed. The Water Bureau and the Gas Company have comprehensive pipe systems in every direction. The Maryland Pipe Line Company has a short stretch of line through which oil is piped into the city, which is a part of its transcontinental system.

PRELIMINARY STUDIES

The first question that presented itself to the committee was whether or not a general survey of electrolysis conditions in the city should be made as a starting point for future work. It was suggested that the National Bureau of Standards be asked to assist in the work and the cost be borne by the underground structure owning agencies in proportion to the amount of equipment owned by each. From a cursory review it appeared that conditions were not as bad in Baltimore as had been found in some other cities, and hence it was decided to first make a compilation of all the information collected by the various agencies in the city who had been studying the problem during the past few years. Accordingly, maps were prepared showing potential readings taken during the previous years by each agency and indicating points where failures due to electrolysis had occurred. Other pertinent data were assembled. From these it appeared that there were only two sections of the city in which dangerous conditions existed, and it was in these sections where practically all failures attributable to electrolysis during the past few years had occurred. Continual changes in the underground pipe and cable systems were causing such rapid shifts in drainage paths and in rail potentials that it was deemed advisable to concentrate on these sections where dangerous conditions had been found, rather than to undertake a comprehensive survey of conditions through the entire city.

ORGANIZATION OF INVESTIGATING COMMITTEE

A sub-committee was formed, consisting of technical assistants from the water department, the electrical commission, the railways

TABLE 1

Potential readings between underground structures at Belair Road and Erdman Avenue, February 9, 1926

a. Averages of potential readings (ten-second intervals)

	WATER MAIN	GAS MAIN	EARTH	UNITED RAILWAYS RAILS	CHESAPEAKE AND POTOMAC CABLE SHEATHS	CONSOLIDATED AND UNITED RAILWAYS CABLE SHEATHS	DRAIN WIRE SHERWOOD SOUTH OF DARLEY
Water Main	0	0.35+	0.67+	0.78+	4.77+	5.43+	13.24+
Gas	0.35−	0	0.32+	0.43+	4.42+	5.08+	12.89+
Earth	0.67−	0.32−	0	0.11+	4.10+	4.76+	12.57+
United Railway rails	0.78−	0.43−	0.11−	0	3.99+	4.65+	12.46+
Chesapeake and Potomac cable sheath	4.77−	4.42−	4.10−	3.99−	0	0.66+	8.47+
Consolidated and United Railway sheath	5.43−	5.08−	4.76−	4.65−	0.66−	0	7.81+
Drain wire*	13.24−	12.89−	12.57−	12.46−	8.47−	7.81−	0

* Sherwood Avenue south of Darley Avenue—voltage drop from here to negative bus estimated 1 volt. Readings were taken for fifteen minutes at ten-second intervals beginning 10:20 a.m.

b. Details of readings at ten-second intervals between rail and water mains

TIME	10:20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
0	+0.5	+0.1	+0.2	+0.3	−1.3	−0.8	−0.7	−1.8	−1.6	+1.3	−1.6	+1.1	−0.9	−1.0	−1.9
10	−1.3	−0.8	−0.1	−1.6	0.5	−0.5	−0.7	−1.0	−1.0	+0.4	−0.3	−2.6	−0.8	−1.6	−0.5
20	−0.3	+2.2	−0.2	−1.2	−1.3	−0.6	−0.4	−0.1	−1.5	−1.6	−2.2	+0.2	+0.4	−1.7	−1.1
30	0.0	−0.5	−0.3	−1.1	+1.3	−0.2	−0.7	−1.5	−3.2	−0.8	−3.3	−3.0	+0.5	+0.5	−2.2
40	−3.2	−0.5	−1.4	−1.2	+0.2	−1.6	+0.1	−2.1	−0.4	−1.3	−0.1	−1.5	−0.6	−1.0	−1.2
50	−0.8	−0.6	+1.2	−1.6	−1.6	−1.7	−1.1	−1.4	−0.6	+1.6	−0.2	−0.6	−2.3	−1.1	−0.6

Average = 0.781−.

TABLE 2

Typical instantaneous potential readings between telephone cables and other underground structures

TABLE 2

Typical instantaneous potential readings between telephone cables and other underground structures

DATE	LOCATION	MANHOLE BOTTOM	RAILROAD RAILS	WATER MAIN	GAS MAIN	TELEPHONE CABLES TO CITY CABLES	CITY CABLES TO SUMP	TIME
September 29, 1926	Philadelphia Road and Streeper	0.6−		0.6−		0.2+	0.6−	10:25 a.m.
	Philadelphia Road and Belnord	0.6−		0.8−		0.1+	0.4−	10:35 a.m.
	Philadelphia Road and Glover	0.6−			0.4−	0.1−	S−	10:45 a.m.
	Fayette and Rose	0.8−	1.6−		0.8−	0.2−	0.2−	10:55 a.m.
	Fayette and Port	0.6−	1.2−	0.4−		0.2−	T−	11:25 a.m.
	Fayette and Bradford	0.8−	1.2−		0.4−	0.2−	0.6−	11:30 a.m.
	Fayette and Madeira	0.4−	1.6−	0.8−		0.2−	0.6−	11:40 a.m.
	Fayette and Duncan	0.6−	1.4−		0.6−	0.1−	0.4−	11:50 a.m.
	Fayette and Castle	0.8−	1.4−		0.6−	0.2−	0.4−	12.00 noon
	Fayette and Chapel	0.8−	1.6−		0.6−	0.2−	0.6−	1:10 p.m.
	Fayette and Wolfe	1.0−	1.2−	0.6−		0.2−	0.4−	1:20 p.m.
	Fayette and Bethel	0.6−	1.2−			S−	0.2−	1:45 p.m.
	Fayette and Aisquith	0.4−	1.0−	0.4−		0.2−	0.4−	2:30 p.m.
	Fayette and East	0.4−		0.4−		0.1+	0.4−	2:40 p.m.
	Fayette and High	0.2−		0.2−		0.2−	S−	3:05 p.m.
	Fayette and Harrison	0.2−				0.2−	0.4−	3:45 p.m.
	Fayette and Frederick	0.2−		S+		S+	0.4−	4:00 p.m.
September 30, 1926	Fayette and E. Gay	S−	1.8−	0.2−		0.2+	0.4−	9:20 a.m.
	Fayette and Holliday	0.2−	1.0−			S−	S−	9:30 a.m.
	Fayette and Guilford	0.2−	1.2−			S−	S−	9:40 a.m.
	Light and Baltimore	0.2−	1.0−	0.1+		0.4−	0.4−	11:10 a.m.
	Redwood and Hopkins	0.6−	1.6−			0.2−	0.4−	1:20 p.m.
	Redwood and Liberty W.	0.6−	1.6−	0.2−		0.2−	0.4−	1:50. p.m
	Redwood and Eutaw	0.8−	1.2−	0.8−		0.2−	0.4−	2:15 p.m.
	Redwood and Greene	0.8−		1.2−		1.6−	S+	2:35 p.m.
	Redwood and Pennsylvania Avenue	0.8−				1.6−	0.2+	2:55 p.m.

company, and the gas company, under the leadership of Mr. F. T. Iddings of the telephone company, whose name in this section is synonymous with electrolysis, and a detailed survey was begun of one section in the eastern part of the city in which the worst conditions had been found. The recent joining together of two previously isolated water systems, the rapid development of all underground systems due to industrial expansion, and an absence of comprehensive mitigative measures all pointed to the advisability of the survey in this section. Later, other sections were studied in a like manner, and mitigative measures agreed upon by members of the committee. Measurements were made of the potential gradient on the rails and the instantaneous potential differences between all structures at strategic points, and these were plotted against the railway loads. In some cases where great potential differences were found, the amount of current being returned by the underground systems was measured. The telephone company, on its own initiative, has for some years been making a general survey of electrolysis conditions over its cable system which covers practically the whole city. This survey during the last year was extended to all underground structures in the vicinity of the company's cables. In this way a fair picture of conditions generally was found.

Results of the studies and surveys of the sub-committee are laid before the general committee and made available to all parties concerned. Any recommendations made by the sub-committee are considered and passed upon by the general committee and a method of procedure decided upon. All problems are approached with a spirit of coöperation, and for this reason, no vexatious questions tending to halt improvement in conditions nor any problems which were incapable of solution have yet arisen before the committee. Mitigative measures have generally fallen into three classes,—coöperative construction, proper drainage, and construction of automatic substations by the railways company.

DRAINAGE AND AUTOMATIC SUBSTATIONS

Before any construction of any importance is undertaken by any company or city department, plans are first discussed in committee meetings; where it appears likely that electrolysis conditions will be unbalanced, changes are suggested and where changes appear impractical, mitigative measures are provided for. Studies in the area affected are taken both before and after the construction is

completed. The railways company has evidenced great willingness to supply adequate drainage wires and the other coöperating agencies have freely availed themselves of this privilege. In some cases, overdrainage has been found to result, due to shifting conditions. Each of the agencies involved provides a certain amount of drainage for its own system. All of these drainage wires are being made a part of the general drainage system. The railways company makes a continual investigation of its bonds; for the past few years less than 2 per cent of all bonds in the city have been found to be defective, which fact is a potent factor in reducing electrolytic losses. This company has also adopted a program for the installation of additional sub-stations—all automatic—their locations being worked out as far as possible to improve electrolysis conditions.

DIFFICULTIES WITH JOINTS

Pipe joints and insulated rail joints have resulted in some little annoyance due largely to the uncertain conditions which they produced before the committee started to function. The removal of insulating joints on either side of a submarine cable and a provision for additional drainage eliminated one case of electrolysis which had been troublesome for years. In another case, an insulating joint was found to have been installed in the rails near a sub-station, causing a potential gradient of 30.5 volts per 1000 feet. Removal of the joint reduced the gradient to 4.3 volts. Cement joints used in gas pipes have been found to result in some flow of current between gas and water pipes; in one case twelve amperes were found passing through a bond in the basement of a residence. It is believed that leadite joints in water pipes cause a very uncertain condition, due largely to the rapid decrease of resistance with age. It is evident that some method for the protection of water and gas services which closely approach other structures should be developed. With the rapid spreading out of both of these systems and the meeting of the services with small telephone block cables at very vulnerable points, it is not always expedient to supply proper electrical protection to these small ends. The water department is resorting to the use of cast iron for services of 2 inches and over, in order to reduce the conductance and the liability to damage. It is true, of course, that damage to services and block cables is not as serious as that to feeder and transmission systems, but it can nevertheless be very troublesome.

ADVANTAGE OF COÖPERATIVE CONTROL

The most important thing that the Electrolysis Survey Committee has brought about is a manifestation of a spirit of coöperation which motivates all of the underground structure owning agencies in the city. A medium is provided by which differences of opinion can be ironed out and steps taken that will react to the benefit of all. Isolated remedies applied by a single agency are no longer thought of. The total number of failures due to electrolysis has shown a slight decrease since the committee started its work, which fact, in view of the rapid expansion of the underground systems during the past few years, indicates progress in mitigative measures. Inasmuch as many failures occur as a result of conditions which have been existing for a number of years, it is evident that the full benefit of the committee's work will not be apparent for a long time. Certainly it is true that Baltimore is remarkaby free of electrolysis troubles, but it is the aim of the committee to effect even greater improvement, inasmuch as the damage done by electrolysis is in no way measured by the number of failures which occur.

The coöperative method which has been the rule in Baltimore for the past five years commends itself for the attacking of the vexatious electrolysis problem and is worthy of emulation in other cities.

EXPERIENCES WITH GOOSE-NECKS, OR SERVICE CONNECTIONS, OF LEAD, WROUGHT IRON AND COPPER[1]

By Emil L. Nuebling[2]

The service pipes and connections of the Reading, Pa., water works were and are still installed by and at the expense of the property owners. The work is generally performed by a plumber. No rule or regulation, however, prohibits any other competent person from installing service lines.

The corporation cocks were always installed by the operators of the water works. The original cocks had a tapered tail piece which was driven into a drilled and taper-reamed hole located at the top of the water main. A pliable connection with the service pipe was made with a lead goose-neck. This method was also used after the introduction of the first modern tapping machine, which permitted the making of ½- to 1-inch diameter taps. When it was observed that some service installations were being made with light weight pipe, the water works officials had rules adopted specifying the minimum permissible weights of lead pipe that should be used. The specified weights were then listed as Class A. A. No serious trouble was thereafter experienced with service pipe connections until after the introduction of a larger tapping machine, which permitted the making of taps up to 2 inches in diameter.

Since no additional rule was made as to the weight requirements, of the larger sizes of lead pipes and connections, the same class as specified for the smaller sizes was used in installing the larger sizes. Some time after the installation of a number of the larger sizes of service connections, a good percentage of them split open; especially those of the largest size. The writer, who was then in charge of the water works, was surprised at the results of calculations made of the strengths of the various sizes of lead pipes. The so-called classes, "Strong," "Extra Strong" and "Extra Extra Strong," did not carry the same degree of strength throughout the different sizes of pipes,

[1] Presented before the Chicago Convention, June 9, 1927.

[2] Consulting Engineer, Reading, Pa.

but, under any class, the strength of the smaller diameters of pipes was far in excess of requirements and that of the larger sizes was considerably below the pressures to which they were subjected. This is clearly shown in table 1, which shows, for example, that a ½-inch "Extra Strong" lead pipe will safely withstand a working pressure of 220 pounds per square inch, while a 2-inch "Extra Strong" lead pipe will only take care of 69 pounds per square inch.

The regulations pertaining to service pipes were then changed to permit lead pipes of the following minimum weights: ½-inch, 2 pounds; 4-inch, 3½ pounds; 1-inch, 6 pounds; and to prohibit the use of lead in service pipes or connections in sizes of 1¼ inches in diameter and larger. For these sizes a flexible joint (permitting some settlement of main line, service line or both without pulling out or breaking off at the joints), was then required. The rule as adopted is,

> Where 1¼-, 1½-, and 2-inch corporation cocks are used, the service pipe shall be connected without the use of lead pipe by means of straight long turn elbows, nipples and "Kewanee" or all brass unions. All fittings other than unions shall be either galvanized wrought or malleable iron, lead-lined wrought or malleable iron or cast iron. The first elbow shall be attached to the corporation cock and followed with nipples, union and second elbow for a distance of approximately nine diameters of the pipe from center to center of elbows. The direction of this portion of the connection shall be approximately in line with the water main. The next portion of the connection shall consist of a nipple and a third elbow and be not less than six diameters in length, between elbow centers, and shall extend upwards or downwards to reach the proper depth of the service pipe. The outlet of the third elbow shall run at right angles with the main.

The corporation cock for these installations was inserted horizontally on the side of the main pipe line. It was and is now rather difficult to purchase long turn elbows, because so few supply-houses keep them in stock. So, after a trench had been left open for several days, while the plumber was endeavoring to get hold of some long turn elbows, the nuisance of the open trench was abated by permitting the plumber to substitute short turn elbows, which, with three of them in the line rather closely bunched, did not aid the flow of water greatly by reason of the excess friction created.

COPPER SERVICES

The copper service pipes and connections, recently put upon the market by one of the largest manufacturers of water works brass

TABLE 1

Relative strengths of lead and copper service pipes

The pipes will withstand, in addition to the safe internal pressures listed, a 50 per cent increase allowed to take care of water ram. The ultimate cohesion of lead is taken at 2000 and that of copper at 30,000 pounds per square inch, each with a factor of safety of 5.

LEAD PIPE									MUELLER COPPER PIPE			
Extra Strong—A. A.					Extra Extra Strong—A. A. A.							
Nominal inside diameter	Actual outside diameter	Calculated inside diameter based on outside diameter and weight	Weight	Safe internal pressure	Actual outside diameter	Calculated inside diameter based on outside diameter and weight	Weight	Safe internal pressure	Outside diameter	Thickness B. W. G.	Thickness	Safe internal pressure
inches	*inches*	*inches*	*pounds per foot*	*pounds per square inch*	*inches*	*inches*	*pounds per foot*	*pounds per square inch*	*inches*		*inches*	*pounds per square inch*
½	0.96	0.5255	2.5	220	1.04	0.5542	3.0	233	⅜	18	0.049	744
¾	1.21	0.7487	3.5	164	1.27	0.7617	4.0	178	½	16	0.065	698
1	1.48	0.9819	4.75	135	1.59	0.9895	6.0	162	⅝	16	0.065	523
1¼	1.76	1.2444	6.0	110	1.83	1.2674	6.75	118	⅞	16	0.065	418
1½	2.07	1.4898	8.0	104	2.15	1.5163	9.0	111	1⅛	15	0.072	389
2	2.51	1.9941	9.0	69	2.61	2.0011	10¾	81	2⅛	14	0.083	301

TABLE 2

Desirable materials for services and goose-necks

DIAMETER	MATERIALS FOR SERVICE PIPES	MATERIALS FOR GOOSE-NECKS
inches		
½ ¾ 1	Copper or brass, lead, lead or tin-lined genuine wrought iron, genuine galvanized wrought iron	Copper Lead
1¼ 1½ 2	Copper or brass, cast iron*, lead or tin-lined genuine wrought iron, genuine galvanized wrought iron	Copper
Above 2	Cast iron, genuine galvanized wrought iron	No goose-necks

* If made heavy enough to withstand external forces including rough handling.

goods, have demonstrated their great value as mediums for joining service lines to corporation cocks as well as good materials for the service pipes. The strengths of these pipes as shown in table 1 should be compared with corresponding sizes of lead pipes. The strength to resist internal pressure is considerably above the actual requirements, brought about, no doubt, by an added thickness of metal for withstanding external pressures.

Sizes up to and including one-inch in diameter have been on the market and in use for some time. When copper pipes and connections are available and used for the larger sizes then all future difficulties with these service pipes and goose-necks will, undoubtedly, be avoided.

DESIRABLE MATERIALS FOR SERVICES

In the opinion of the writer the desirable materials for service pipes and goose-necks of the various sizes are listed in table 2. The materials are listed in the order of preference. The list does not contain cement-lined pipe, because the writer has had no experience with it.

PROGRESS OF WATER TREATMENT ON RAILROADS[1]

By R. E. Coughlan[2]

To the men who are in daily contact with the trouble experienced from the use of water unsuitable for the generation of steam, no argument is necessary to show the need of water treatment.

As 90 per cent of a railroad's water supply is utilized for steam making purposes, this subject has been one of importance for many years. Scale forming salts must be removed and corrosion retarded, if economical results of boiler operation are to be obtained.

Corrosion of boilers has been one of the problems of railroads for many years. In 1868, the old American Railway Master Mechanics Association reported on this subject, laying particular stress upon the quality of the water as being one of the important factors.

Practically all railroads have some soft water, as well as water which should be treated before it is used in boilers.

Our present day water softening plants are the outcome of a process invented by Dr. Thomas Clark of Aberdeen, Scotland, in 1841. Previously, Cavendish in 1776, and Henry, in the latter part of the eighteenth century, discovered that caustic lime or lime water, when added to a natural water, would throw the carbonates of lime and magnesia out of solution. Clark was the first to apply this principle to soften water. It was some years later that Porter suggested the use of soda ash with lime. This was the start of the lime and soda ash process now used extensively. Although the principles and reactions of water softening have been known for many years, it has only been since 1880 that much advancement has been made in the United States.

The early water softening plants were of the intermittent type and many experiments were necessary before our present day continuous type of plant was perfected. Even today, the intermittent

[1] Presented before the Boiler Feed Water Studies' meeting, Buffalo Convention, June 9, 1926.

[2] Supervisor of Water Supply, Chicago and North Western Railway Company, Chicago, Ill.

type of plant is used on many installations where local conditions warrant it.

For a number of years, the reagents were added directly to the water in the locomotive tank. The resulting sludge being carried into the boiler caused considerable foam trouble which handicapped efficient treatment.

The progress of complete treatment of water before it entered the boiler has been marked by very interesting results and surprising revelations to the mechanical men who are responsible for the efficiency of boilers. In the early days, it was considered that anything that was wet could be utilized for steam purposes. If the boiler failed, due to leaking or foaming, it was taken as a matter of course. The larger locomotives, longer runs and faster schedules required increased efficiency of the locomotives. This demanded better water for steam making and water treatment has met the demand.

The western railroads, due to the poor quality of the water available in their territories, have taken the initiative in the installation of water treating facilities, and it is on the western railroads that the most marked improvement has been noticed.

WATER TREATMENT ON THE CHICAGO AND NORTH WESTERN RAILWAY

On the Chicago and North Western Railway, practically all of the water supplied to boilers, except that obtained from lakes and rivers of northern Wisconsin and northern Michigan, requires treatment. Partial treatment and internal treatment have been used for many years. The extensive water treatment program by the Chicago and North Western Railway was started in 1903 when sixteen lime and soda ash treating plants were built in Iowa, where the water is hard, due to the large quantity of sulphates of magnesia and lime contained in solution. These were the pioneer water softening plants in that section of the country, and have been added to from time to time, until, at present, there are forty-seven lime and soda ash water softeners in operation and ten more under construction. These are supplemented by partial treatment and internal treatment where local conditions warrant it. Intermittent types of softeners were the first installations.

In 1922, the first continuous type softener was installed. Where internal treatment is used, this treatment is controlled by means of chemical tests made on samples of water taken from the boilers at

each terminal. Simple feeding devices regulate the amount of treatment.

The 1925 volume of the Railway Engineering and Maintenance Encyclopedia states that approximately 1000 water softeners are now operated by the railroads of the United States, removing 100,000,000 pounds of scale annually at approximate saving of $13,000,000 per year.

This annual saving is directly reflected in the operating report of each railroad so equipped. The boiler failures report of the Chicago and North Western Railway Company for 1910 shows 2132 failures, chargeable to water conditions. The same report for 1925 shows 37 failures. The monthly boiler failure report for February, 1910, shows as follows:

Boiler failure report for month of February, 1910

Cause of failure:	
Leaking flues	319
Leaking fireboxes	22
Leaking arch tubes	0
Flues burst	3
Arch tubes burst	30
Foaming	17
Total	394

The same report for February, 1926, shows as follows:

Boiler failure report for month of February, 1926

Cause of failure:	
Leaking flues	0
Leaking fireboxes	0
Leaking arch tubes	0
Flues burst	0
Arch tubes burst	0
Foaming	0
Total	0

Water treatment is one of the essential factors which make it possible to obtain the longer daily mileage which most railroads are now receiving from locomotives in passenger service. A few years ago, it was the practice to change locomotives about every 100 to 150 miles. Now many railroads that are equipped with water softening plants use only one locomotive for continuous runs of much longer mileage.

The Chicago and North Western Railway now operates locomotives in passenger service from Clinton, Iowa, to Omaha, Nebraska, a distance of 350 miles. These locomotives make a round trip of 700 miles each day. Another western railroad operates locomotives in passenger service 600 miles without change, while still another has completed test runs of over 1700 miles, one locomotive pulling the train the entire distance.

PITTING OF FLUES AND BOILER CORROSION

With the problem of incrustation of boilers practically under control, more attention is now being given to the pitting of flues and the corrosion of boiler sheet. Many theories as to the cause of this trouble have confused the issue. Many committees have held symposiums on the subject. The railroad water service engineers have not been idle, although their work has been somewhat hampered, due to incomplete records and the increasing evaporating power of boilers. When it was found that removing the scale did not prevent corrosion, further studies have been made along three special lines, namely:

1. Use of feed water heaters to eliminate oxygen
2. Counter-electrical potential devices
3. Excess treatment

The first two of these methods are still in the experimental stage, each method having its respective merits and adherents. The excess treatment method has shown great possibilities where it is practicable to apply it in the railroad service. This method, proven in the laboratory, consists in the addition of an excess of caustic soda, caustic lime or sodium carbonate over that required to combine with the scale forming salts. The success of this treatment depends upon uniformity of treatment over an entire locomotive district to prevent foaming. Where it is possible to secure this uniformity, high concentration of alkaline salts are carried in the boilers with practically no foam trouble.

The Chicago and North Western Railway Company has a locomotive district where 50 per cent of the natural water contains over 50 grains per gallon of sodium carbonate. By treatment of the remaining water to a similar composition, a concentration of over 8 per cent normal alkalinity is carried without trouble. Pitting and corrosion on this district is unknown and, needless to say, the boilers

are clean. Additional lime and soda ash softeners are being installed on other locomotive districts as rapidly as funds become available, so that in a short time this method of treatment will be in general use.

One of the railroads having 71 lime and soda ash softeners in operation is treating the water to less than 1 grain per gallon hardness, leaving in the water an excess of lime and soda ash for the purpose of eliminating pitted flues. This program was started early in 1922, and very gratifying results had been obtained. The boilers carry a very high percentage of alkaline concentration, with very little trouble.

The quality of the material used in boiler construction has also been thoroughly investigated. At the present time, most of the railroads have standard specifications for boiler steel. These specifications are strictly adhered to in order to avoid the use of non-homogeneous steel which may set up electrolytic reaction, leading to corrosion.

Protective coatings of lead or similar material have also been used with varying degrees of success.

While the entire principles of water softening and the control of corrosion may be explained theoretically in very simple terms, practical applications are sometimes very difficult. Experimenting with the boiler of a locomotive in operation is entirely different from research work conducted in a laboratory. Foam trouble and priming cannot be tolerated. The water service engineer must be sure of the results. Movement of trains safely is the first consideration. Progress can only be attained with the co-operation of all departments.

The enviable records made by the railroads of today in efficient, economical operation show that the progressive railroad managements recognize the value of soft water for boiler use. The proof of this is in the increased softening facilities installed each year. The progress made in water treatment on the railroads of the United States shows that eliminating costly boiler maintenance is one of the important ways of reducing the cost of operation when the natural water available is unsuitable for boiler use.

OPERATION OF THE NEW WATER SOFTENING PLANT AT SPRINGFIELD, ILLINOIS[1]

By Charles H. Spaulding[2]

During the past thirty-seven years Springfield has developed a ground water supply in an effort to avoid the use of surface water. The development was first by infiltration galleries constructed through coarse gravel at a depth of about 20 feet. Nearly 3000 feet of these tunnels were built, but, as they became inadequate, wells were driven in the glacial drift of the river bottom and the supply augumented by adding more wells from time to time. This combination has usually yielded a fairly potable supply, but not without serious faults. The ground water contained iron in such quantities that meters and service pipes required frequent repairs and replacements, plumbing and laundry were stained and any unusual currents in the distribution system produced roily water at the taps. Moreover the hardness of the water was a source of needless expense to users in causing excessive soap consumption and repairs to water coils, heaters and plumbing in general. Furthermore the ground water required chlorination to reduce the bacterial content to the standard established by the United States Public Health Service. Finally, it became increasingly difficult to obtain sufficient quantity from this source. At the same time the pollution of the Sangamon River increased so that the use of this source without purification became more and more a menace to the health of the city.

A study of these problems over a period of ten years or more led to the construction of a water softening plant capable of handling either surface or ground water.

DESCRIPTION OF PLANT

The raw water is collected in a well 60 feet in diameter by 53 feet deep to which it flows by gravity from the galleries or the river or

[1] Condensed from papers presented before the Iowa Section and the Illinois Section meetings, November 4, 1926, and January 27, 1927.

[2] Chemist and Superintendent, Water Purification, Department of Water, Light and Power, Springfield, Ill.

is pumped from the tubular wells. Low lift pumps deliver the raw water to the dosing well at the end of the head house adjoining the chemical preparation room, where lime and coagulant are added. Thence it passes to two parallel reaction chambers where it is stirred by mechanical agitators revolving at $\frac{3}{5}$ r.p.m. The chambers are 42 feet 8 inches in diameter and the speed of the paddles at the two-thirds point is therefore 0.8 foot per second. The mixing period is 40 minutes at the nominal plant capacity of 12 m.g.d.

From the mixing chambers the water passes through two Dorr clarifiers in parallel, thence through settling basins having carbonating chambers at the outlet ends and finally to eight filter units of the rapid sand type. The detention period in the Dorr clarifiers is one hour and thirty minutes and in the settling basins four hours. The carbonating chambers provide thirty minutes further detention.

The filtered water is chlorinated in the conduit leading from the filter building to a filtered water reservoir of two million gallons capacity.

Equipment for lime handling

One feature of the Springfield plant which has proved very satisfactory is the lime unloading equipment. Quick lime is used because of its lower first cost and higher softening value than hydrated lime. The material is received in bulk and unloaded by means of a vacuum conveyor which lifts it to the third floor of the head house where a screw conveyor distributes it to the three lime bins. With this machine all dust is eliminated around the unloading platform and to a large extent throughout the plant. The task of unloading is reduced to ordinary routine requiring men of no special hardihood or tolerance for lime. The machine best handles pebble lime 1 to 2 inches in diameter containing little fines or dust. However, it will successfully handle ordinary crushed lime providing the size is below 2 inches so that lumps cannot become wedged in the suction line. Smooth clean pebbles roll easily to the suction nozzle while fine or angular pieces require more shoveling. There is no perceptible air slaking during cold weather. In warm weather there is probably some absorption of moisture, but from our experience it is but a fraction of a per cent so that we have not been sure that such difference as we found was not due to errors in sampling. The cost of operating the "Airveyor," as the unloading equipment is called, is 10 to 20 cents per ton, depending on the condition of the lime in the car and

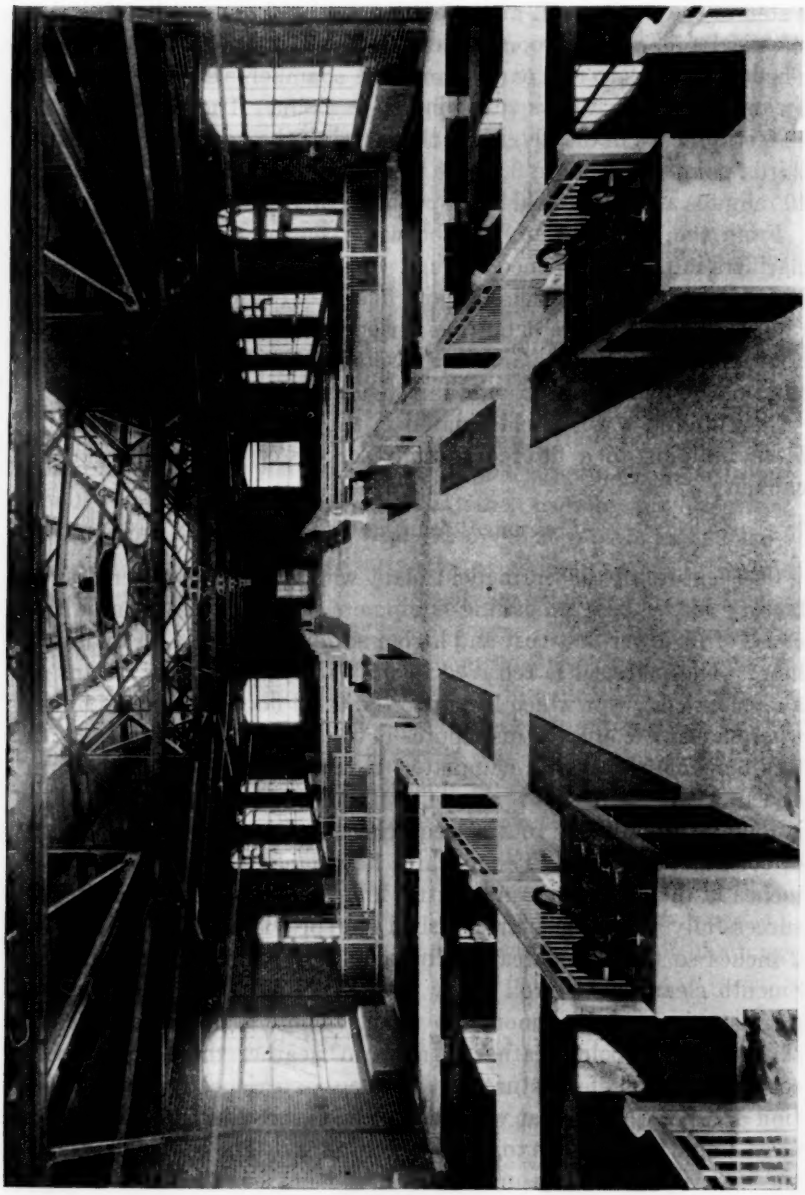

FIG. 1. INTERIOR OF FILTER HOUSE

the amount of shoveling required. The installation was furnished by the Guarantee Construction Company of New York.

Lime from the bins drops by gravity into weighing hoppers and thence into slakers. The original method of handling from this

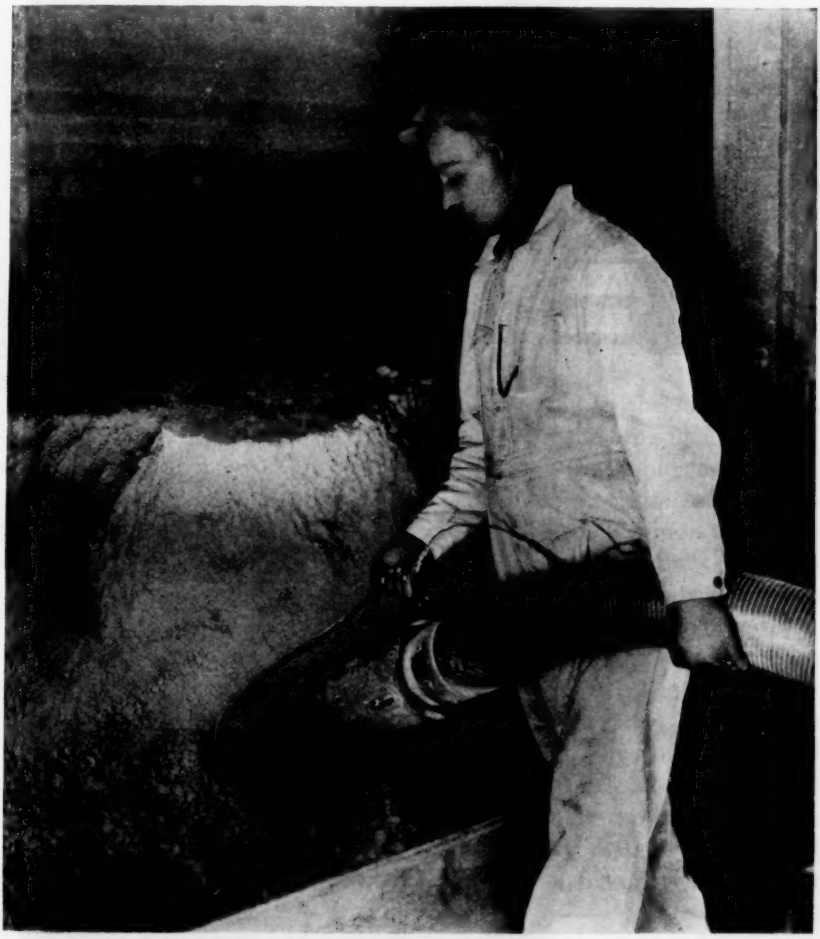

FIG. 2. UNLOADING LIME WITH "AIRVEYOR"

point has been changed and this feature will be explained in some detail.

In the original design the lime suspension was made up in 7000 gallon batch tanks, of which there were three, located in the base-

FIG. 1. INTERIOR OF FILTER HOUSE

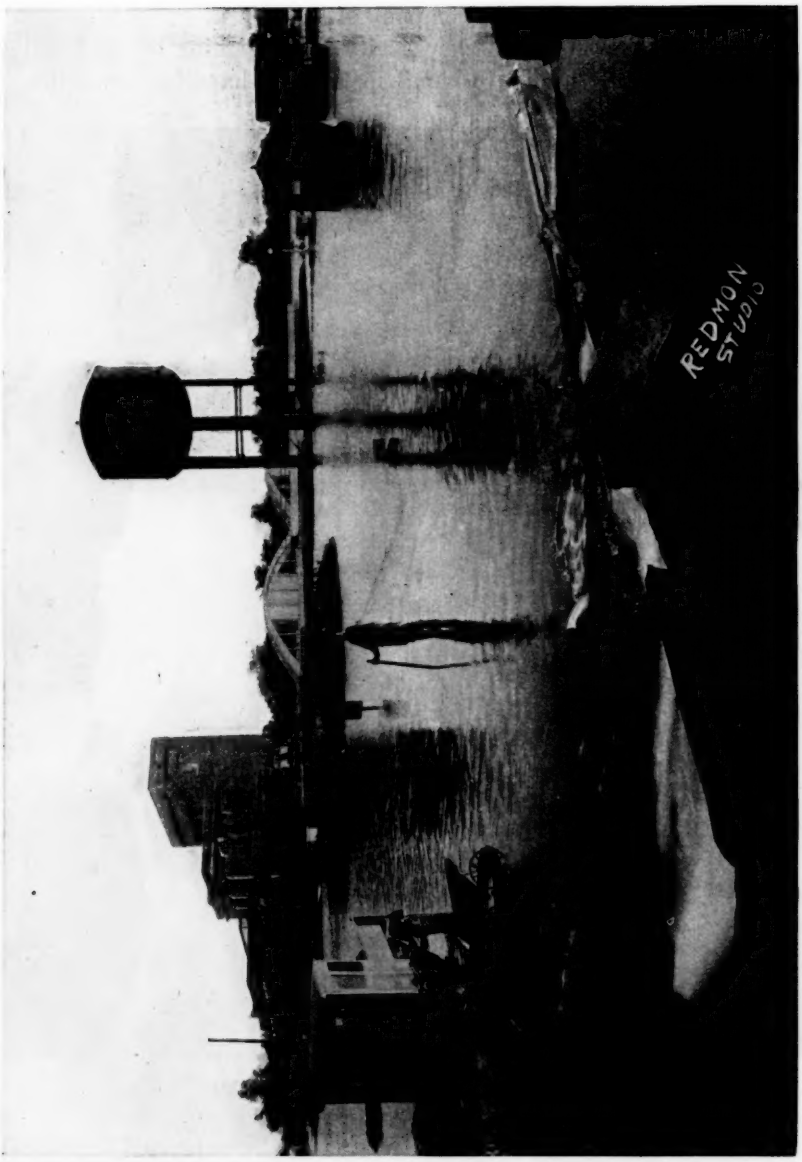

FIG. 3. HIGH WATER AT PLANT

ment of the head house, one beneath each slaker. The lime was dropped into the batch tanks from the slakers and diluted to the desired strength. Agitating paddles kept the lime in suspension of even strength and a steam jet elevated the liquid to the proportioning machines located over the dosing well. Due to rapid scaling of the discharge line from the steam jets, the jets were replaced by a small centrifugal pump which gave less trouble.

About this time, however, we found that several plants were using dry feeders successfully with pebble lime and we began to investigate the suitability of some such method for this plant. The result of the study was the elimination of feeders, wet or dry, and the proportioning of the lime by hourly weighing into the slaker. A constant stream of water, sufficient to about equal the contents of the slaker once an hour passes through the slaker tank and carries the lime to the dosing well through the gravity line. This eliminates the batch tanks, pumps and measuring machines and greatly simplifies operation.

FIG. 3. HIGH WATER AT PLANT

Several objections to such a method arise. In the first place it would seem that some of the lime might leave the tank unslaked and thus be lost. However, the temperature of the liquid leaving the tank rises and falls in strict accord with the concentration of the lime, which would not be the case if hydration were lagging. It seems likely that unslaked lime remains on the bottom of the tank until hydrated—a matter of minutes, since the water is always warm (35° to 70°C.) due to heat of hydration, no extra heat being required. The lime is all accounted for in the chemical reactions. Another possible objection might be that the water would not be evenly treated, but this is rather an advantage in our case. It may be looked upon as a variation of the method of split treatment proposed and used by C. P. Hoover at Columbus, by which all of the lime is added to half or more of the raw water, adding the balance of the raw water later. The result should be better magnesium removal and a lower hardness in the plant effluent. This effect is obtained as shown in table 1.

Three successive ten-day periods have been compared in which the theoretical lime requirements happen to be nearly identical. In the second period the raw water should require 5 pounds more per million gallons than in the first and in the third period it should require 15 pounds more per million gallons assuming the same magnesium removal in all three periods. The results show the treatment

was nearly as satisfactory in the second period with 53 pounds less per million gallons, while in the third period removals of temporary hardness and magnesium were better by 11 and 10 p.p.m. respectively.

The fluctuation in treatment is in the neighborhood of 100 per cent. This is smoothed out to about 4 per cent at the outlet of the mixing chambers and about 2 per cent leaving the clarifiers. It cannot be detected in the water applied to the filters. The interval of dosing will necessarily depend on the rate at which the plant is operating.

TABLE 1

Comparison of softening results when dosing continuously and periodically

	NOVEMBER 6 TO 15	NOVEMBER 16 TO 25	NOVEMBER 26 TO DECEMBER 5
	Dosing interval		
	Continuous	30 minutes	60 minutes
Raw Water:			
Total alkalinity	238	236	223
Carbon dioxide	25	28	43
Magnesium	113	113	116
Non-carbonate hardness	43	45	56
Filtered water:			
Total alkalinity	59	61	48
Bicarbonate alkalinity	7	21	4
Magnesium	82	79	75
Magnesium removed	31	34	41
Chemicals used, pounds per million gallons:			
Lime, 89 per cent CaO	1,560	1,507	1,577
Aluminum sulphate	44	56	49

Analyses expressed in parts per million of equivalent $CaCO_3$.

The hourly interval which we are using would have to be reduced, if the rate were increased much over 7 m.g.d. At this rate the theoretical detention in the mixing chambers is one hour and six minutes. Actually it takes only thirty minutes for a change in treatment to appear at the mixing chamber outlet.

We have found the accessibility of mechanical mixing chambers is an advantage in cleaning. Quick lime, especially pebble lime, contains considerable quantities of unburned sandy core which settles in the mixing chamber and requires flushing out. The speed of

rotation of the paddles is somewhat too low in our opinion. A sample of water taken at the outlet will show considerable lower alkalinity if shaken a few minutes. Just how much more agitation would be profitable has not been determined as yet, but it is one of the advantages of mechanical agitation that this can be obtained without any limiting conditions of loss of head.

Continuous removal of sludge from clarifiers

A feature of the plant which proved valuable during the recent high water is the continuous removal of sludge from the clarifiers. For a period of six weeks it would have been impossible to drain the basins for cleaning and if sludge storage had been provided for such a period the basins would have required much larger design. Figure 3 shows the plant when the flood was at its crest and conditions at their worst. The clarifiers are removing about 96 per cent of the precipitated solids which amounted to 342 tons during the month of December. The sludge pumps are lifting about 85,000 gallons per day, half of which is returned to the mixing chambers. This sludge, when tested has shown a density of 4 to 10 per cent solids, averaging 5.5 per cent. The water lost with sludge during such a month amounts to about 0.5 per cent of the water treated. If the basins were operated without clarifiers, they would have required emptying and cleaning at least once each month, losing thereby more than twice as much water. Needless to say, the important fact is that the whole basin is available for sedimentation throughout the month with no loss of efficiency due to draining and filling. There is, of course, some sludge depositing in the main basins beyond the clarifiers. In six months of operation it has accumulated to a depth of 4 feet at the inlet end, sloping to 1 foot at half the length of the basins and 2 inches at the outlet end. The basins have a working depth of 14 feet.

PLANT OPERATION DATA

Chemical and bacteriological data on plant operation are briefly summarized in table 2. No very high turbidities have been encountered during this period, but the reduction through the basins and filters has been satisfactory. The filtered water always appears bright and sparkling in the gate chamber of the clear well, even though the turbidimeter shows measurable values.

The sanitary quality of the raw water fluctuates widely, the bacterial load depending on the proportion of river water used. Thus August, the month of greatest daily pumpage, shows the highest counts, especially of B. coli. The B. coli index of the Sangamon River at Springfield from September to January has been over 27,000 per 100 cc. in spite of unusually high dilution from repeated floods. We have reason to believe it will exceed 150,000 per 100 cc.

TABLE 2

Chemical and bacterial results of water purification

	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	AVERAGE
Turbidity, p.p.m.:							
Raw	38.0	64.0	24.0	9.0	6.0	4.0	24.0
Applied	2.0	3.5	3.5	3.0	2.0	2.0	2.6
Filtered	0.3	0.3	0.3	0.2	0.2	0.2	0.25
Hardness, p.p.m.:							
Raw	274.0	232.0	267.0	260.0	279.0	279.0	265.0
Filtered	145.0	92.0	125.0	102.0	106.0	105.0	112.0
Total bacteria per cubic centimeter, 37.5°C., 24 hours:							
Raw	420.0	3,988.0	395.0	321.0	136.0	48.0	885.0
Clarified	106.0	141.0	73.0	13.0	10.8	2.2	58.0
Applied	64.0	58.0	44.0	11.0	6.9	1.5	31.0
Filtered	36.0	22.0	10.0	5.0	3.4	0.9	13.0
Final effluent	13.0	5.0	4.0	2.0	3.6	0.4	5.0
B. coli per 100 cc.:							
Raw	64.0	7,000.0	1,558.0	242.0	136.0	52.0	1,509.0
Clarified	5.0	139.0	49.0	37.0	7.6	1.3	40.0
Applied	11.0	44.0	6.0	8.0	5.7	0	12.5
Filtered	0.0	3.2	1.0	0.7	0.25	0	0.86
Final effluent	0.2	0.2	0	0.2	0.33	0	0.18

at normal summer stages and the bacterial efficiency of the plant is therefore of vital importance.

The outstanding feature of the bacterial data is the high efficiency of the coagulation basins. Here, we believe, is a striking example of the superior efficiency of softening and coagulation over simple coagulation. The average efficiency of the basins as measured by the B. coli index during this period was 99.2 per cent. Compare this with the average of 75 per cent given by the Manual of Water Works Practice. A basin having an efficiency of 99 per cent will

handle twenty-five times the load that can be handled by a basin of 75 per cent efficiency with the same quality of effluent. It should be mentioned that we cannot credit the above performance to excess lime treatment as hydroxide alkalinity was rare during the period and monthly averages were all on the side of bicarbonate alkalinity. We are inclined to attribute the results partly to heavy, voluminous precipitate and partly to the continuous removal of sludge. The efficiency of the clarifiers with only two and one-half to three hours detention shows a removal of more than 97 per cent of B. coli. These results together with filter and chlorination efficiencies indicate that the plant can handle a load of 10,000 B. coli per 100 cc. with considerable margin of safety.

TABLE 3

Operation statistics

	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	AVERAGE
Total water delivered, million gallons....	183	252	221	214	203	207	213
Length of filter runs, hours.....	21.2	24.0	42.4	57.9	66.2	86.9	49.7
Wash water, per cent..	3.0	3.1	2.8	1.5	0.9	0.7	2.0
Chemicals used, pound per million gallons:							
Lime.....	1,500	1,530	1,493	1,330	1,525	1,632	1,502
Aluminum sulphate.	131	132	56	27	42	54	74
Chlorine.....	3.4	2.9	2.8	1.9	0.5	2.3	2.3

Brief operation statistics are shown in table 3. The length of filter runs increased from 21 to 87 hours, averaging about 50 hours. The ratio of wash water to total water filtered averaged 2 per cent, showing a marked decrease during the six months. The increased runs and decreased wash water accompanied a growth of filter sand which has been stopped at this writing by carbonation. Carbonating equipment was not installed during the period covered by this report and is therefore omitted from consideration. In connection with wash water data it may be said that practically all wash water is returned to the dosing well.

Lime used has averaged 1500 pounds per million gallons, the quantity depending on the amount of hardness removed, carbon dioxide and magnesium in the raw water and also the amount of aluminum sulphate required.

No difficulties of serious consequence have developed in the performance of this plant and we feel that all concerned with the design and construction are to be congratulated. The only change of importance has been in the method of lime application, but this is an inovation hardly to have been anticipated.

The operating personnel, in addition to supervision, consists of five men, viz., one operator on each eight-hour shift, one janitor and one relief operator who maintains equipment and unloads all chemicals with the help of the janitor.

The plant was designed by Burns and McDonnell Engineering Company, with the advice of C. P. Hoover as consulting chemist.

SOME NOTES ON SMALL DIESEL ENGINES

By Huldreich Egli[1]

Thirty years have elapsed since the first commercial Diesel Engine (built by the Machinenfabrik, Augsburg, Germany) was put on the open market. The first commercial Diesel engines were of the four cycle air injection stationary type.

At the termination of the Diesel patents, the comparatively few licensed manufacturers had produced engines aggregating over 500,000 horsepower.

While the four and two cycle air injection type engine was developed to a high degree during Dr. Diesel's stay, the inventor's unsuccessful first attempts, the so-called solid or mechanical injection type engine, was perfected later. The Diesel engine soon became a potent factor in the prime mover field. Today, with millions of horsepowers of marine and stationary engines scattered all over the world, there is little need for further introduction of the Diesel principle.

At the termination of the Diesel patents, a number of concerns started to build Diesel engines. While the pioneers were fully aware of the fact that success of Diesel engines involved as much a metallurgical problem as skillful and conscientious design, they manufactured engines at comparatively low piston speeds and with normal load M.E.P. fully capable of taking as much as 30 per cent overload without the engine showing effects of excessive labor or smoky exhaust. Such apparent liberal margins were exceedingly tempting to the less familiar manufacturers. The greater field of uses and competition gave impulse leading to some speculation in the design of the so-called high speed Diesel engine.

Some manufacturers obviously thought that the combustion was the chief problem to solve. This depends upon the type and size of engine, but the ability to withstand punishment of approximately 2900 degrees Fahrenheit, plus pressures ranging between 450 and 600 pounds per square inch at high frequency, has proved even more a perplexing metallurgical problem than ingenuity of design.

[1] Consulting Engineer, Baltimore, Md.

The air injection type of engine lends itself particularly to combustion adjustment, and, if properly adjusted, the overall efficiency is somewhat in favor of the air injection type of engine over the mechanical injection type. The air injection type of engine requires an air compressor, which is a highly specialized piece of machinery, usually built in three stages, forming an integral part of the engine. The air compressor performs several duties. In addition to administering fuel to the working cylinder, make-up air is needed for starting purposes. Since the injection air is depended upon for oxygen to help combustion, considerably more injection air is needed for heavy loads than for light loads. This is obtained by stepping up the injection air pressure at heavy loads, thus necessitating an oversize compressor in respect to normal load requirements. After all starting air is made up, the surplus capacity is regulated either at the compressor or at the injection bottle by means of throttling a purge valve. This operation is a very simple one, but it requires observation. Should the injection air fall entirely too low, serious consequences may be experienced. Automatic appliances to regulate injection air pressure are not particularly recommended. For larger installations, auxiliary air compressor engine units are often used.

The valves of the engine itself need periodic grinding. The frequency depends somewhat upon operating conditions, but requires the judgement of a competent and conscientious operator. Removing and resetting of valves requires checking of clearances. Incompetency or neglect on this part rapidly produces faulty running conditions and break-downs. Exhaust temperatures should be observed and indicating diagrams should be taken from time to time. Lubrication and cooling water are items of special importance. The life of the engine and economical operation largely depend on these.

In the early days of the Diesel engine, it was customary for a purchaser to send a representative to the manufacturer to familiarize himself with the assembly and operation of the respective engine. Such procedure usually proved to be good investment. It is indisputable that the air injection valve operated Diesel engine, with the very features that make this type of engine superior, when not understood can readily be upset. Many break-downs and failures of Diesel engines were directly attributable to ignorance or neglect on the part of the operator. The well constructed Diesel engine in reality does not require much manual work for the attendant, but the engine must be understood and this requires study and alertness.

It may be safely said that most of the Diesel engines manufactured today have benefited from experience gained from earlier blunders.

Today there are Diesel engines suitable for almost any use, but in the selection of the proper type, operating conditions should be carefully weighed. Whereas the user of larger size engines can afford to hire more talented help, the user of medium and smaller type of engines sometimes is handicapped in this respect. Too much attention to fuel consumption guarantees sometimes misleads the purchaser, as such guarantees are based upon properly adjusted engines.

The part played by the human element under which the engine has to perform its daily routine work has been of much concern to many designers and manufacturers. One point may be gained at the sacrifice of another. At times we believe we have succeeded in eliminating trouble, whereas we find we have merely shifted it elsewhere, but, if we succeed in shifting the trouble where it hurts the least, then we have accomplished something.

To reduce the part played by the human element in the operation of the Diesel engine means reducing the number of adjustments and consequently affecting the flexibility of the engine. In so doing, the engine may be somewhat less economical in fuel consumption at various loads, the usual margin for overload may be narrowed and the range of useful fuels may be somewhat restricted. But if reduction of the number of adjustable parts of the engine means more foolproofness, less first cost and less maintenance cost, these merits should more than offset the slight disadvantages.

The mechanical injection type port scavenging engine is a step in the right direction, this type of engine being particularly useful in medium and smaller sizes where fuel used does not vary to great extent and where skill of attendants is at question. In larger sizes of this type of engine, the problem of combustion becomes considerably more pronounced. Therefore, its usefulness so far is limited to moderate sizes.

For larger sizes of engines, the air injection type will most likely prevail. The same may hold good for high speed engines of smaller sizes.

It may be mentioned here that all exhaust outlets of the Diesel engine should be equipped with high grade thermo-couples so arranged that the attendant may readily check the exhaust temperature of each cylinder. An indicator should be included with the sale of the engine.

In addition to the usual guarantees, manufacturers should pledge themselves to analyze indicating diagrams at least twice a year, free of charge, during the natural life of the engine. This may seem to be a harsh demand upon the manufacturer, but a single expert in the organization could take care of thousands of engines per year, rendering real service to the user.

A STUDY OF THE CHLORINE ABSORPTION OF WATER[1]

By Jacob R. Meadow[2] and Harrison Hale[2]

Inasmuch as a greater part of the chlorine absorbed, as indicated by the chlorine absorption test, is used in oxidizing some organic matter and other oxidizable substances in water, it would seem probable that such a test should give values comparable with the oxygen-consumed value (1) which is used as a standard method in determining the capacity of a water to be oxidized, and hence an indicator as to the carbonaceous organic matter it contains.

The purpose of this investigation has been to compare the permanganate method of oxygen consumed in water analysis with that of the chlorine absorption test by different waters. In doing so, it was hoped that a correlation would be found which would permit the use of the amount of the chlorine absorbed by a given water to determine in a large measure its organic content.

The use of the chlorine absorption test has been studied by Wolman and Enslow (2), and the fact that the five-minute chlorine absorption test would compare very favorably with the permanganate test under certain conditions was shown. Their data disclosed a fairly close variation of chlorine absorption with the oxygen-consumed values of different supplies. They found that the five-minute rate of chlorine absorption shows a decreasing acceleration with increases in pollution as measured by an increase in the oxygen-consumed values. Froboese (3) has investigated the capacity of water to decompose hypochlorites and maintains that this determination is of value in addition to its oxygen-consuming power with permanganates. Keiser (4) has recently made a comparative study of the oxidizability of water as measured by the Kubel-Tiemann method and of the determination of the "chlorine number" of Froboese (3). His results are very interesting and will be referred to later.

Before considering the actual data it is best that some of the principles of each of these tests be taken up. The oxygen-consumed

[1] Research paper No. 53, Journal Series, University of Arkansas.

[2] University of Arkansas, Fayetteville, Arkansas.

test (1) was run according to Standard Methods, using 10 cc. $KMnO_4$ in an acid solution at the temperature of boiling water for thirty minutes. It was found in connection with this that an interesting relation exists between the amount of oxygen consumed and the amount of permanganate first added to the sample. This is shown in table 1.

We see from this that the law of mass action is responsible for the gradual increase in oxygen-consumed values with additional amounts of permanganate. We conclude that the 10 cc. of $KMnO_4$ used in Standard Methods is purely an arbitrary amount.

It may be seen from table 2 that mass action applies to chlorine absorption as well.

What then shall be the arbitrary amount of chlorine introduced in the test? This of course makes the "chlorine number" of Froboese (3) or the "chlorine index" of Pecker (5) uncertain and ill-defined

TABLE 1

Relation of oxygen-consumed value to the amount of $KMnO_4$ used in making the test

	SAMPLE	OXYGEN-CONSUMED VALUES, IN PARTS PER MILLION, WITH DIFFERENT AMOUNTS OF PERMANGANATE				
		5 cc. $KMnO_4$	10 cc. $KMnO_4$	15 cc. $KMnO_4$	20 cc. $KMnO_4$	25 cc. $KMnO_4$
1	Tap water	1.25	1.90	2.03	3.14	5.04
2	Spring	2.10	3.02	4.76	6.10	6.30
3	Well	1.06	1.30	1.75	1.96	2.70

unless we know how much chlorine has been added to obtain such a value. One of the problems, then, is to ascertain what amount of chlorine should be added for such a test.

In the hope of finding a better correlation between the chlorine absorption test and the oxygen-consumed method, a wide series of tests was run on numerous samples of potable and non-potable waters. As many tests were made on each sample as was thought necessary to determine any factors which might influence either method. Various amounts of initial chlorine (a standard solution of chlorine water) were used in the chlorine absorption test. One, three, five and ten parts per million of free chlorine were generally used on each sample, the amount of chlorine absorbed being dependent upon the amount added, as would be expected. The ten-minute absorption test, which seemed to be the most feasible one to use, was adopted

and used throughout. The amount of residual chlorine was determined by both the o-tolidine and starch-iodide methods. It has

TABLE 2

A comparison of the results obtained in using the two methods of determining organic content

NUMBER	SAMPLE	OXYGEN CONSUMED	CHLORINE ABSORBED IN TEN MINUTES AFTER ADDING			
			1.0 p.p.m.	3.0 p.p.m.	5.0 p.p.m.	10.0 p.p.m.
		p.p.m.	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*
1	Tap	1.00	0.10	0.30	0.55	0.95
2	Distilled	1.11	0.12	0.33	0.40	
3	Well	1.15	0.22	0.43	0.47	
4	Spring	1.15	0.31		0.88	1.75
5	Spring	1.15	0.40		2.39	4.21
6	Tap	1.20	0.17			
7	Well	1.20	0.16		0.58	0.86
8	Well	1.30	0.28	0.50	0.60	
9	Well	1.35			0.67	0.92
10	Well	1.36	0.26	0.46	0.75	
11	Well	1.40	0.30	0.45	0.66	
12	Well	1.46	0.27		0.54	0.88
13	Spring	1.47	0.32		0.50	0.92
14	Spring	1.60	0.35		0.80	
15	Well	1.66	0.35	0.70	0.92	
16	Well	1.72	0.53	1.51	1.75	
17	Well	1.74	0.48	1.20	1.54	
18	Spring	1.95			0.35	0.60
19	Spring	2.10	0.61		0.94	1.10
20	Well	2.27		1.54	2.75	3.50
21	Well	2.37	0.46		0.72	0.87
22	Well	2.72	0.50		1.25	1.32
23	Spring	3.02	0.51	0.83	1.00	
24	Well	3.33				0.60
25	Well	3.85				1.54
26	Well	3.85	0.50	1.10	1.33	
27	Well	3.88				0.55
28	Well	4.50	0.59		1.30	2.33
29	Well	4.70	0.53		0.90	1.63
30	Well	4.81	0.51		1.49	1.75
31	Well	5.00	0.80	1.70	2.85	3.94
32	Well	7.10	0.90	1.90	2.95	4.30

been shown by Buswell and Boruff (6) that the two tests are equally good in testing for free chlorine. Analyses were run on thirty or

more different samples, using the standard method for determining the oxygen-consumed value. The data regarding the two tests have been compiled in table 2.

Although in a great many instances the two methods are comparable, strict correlation could not be established between them. The amount of chlorine absorbed does not increase in proportion to the increase in the oxygen-consumed value. This is graphically shown in figure 1.

This lack of correlation is probably due in most cases to the fact that it would take more chlorine than was added to equal in parts per million the available oxygen present in 10 cc. of the permanganate. It will be noted that the chlorine absorbed values with 5.0 p.p.m.

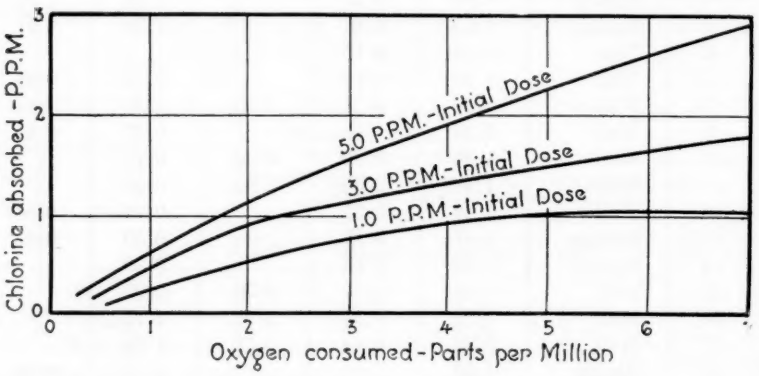

FIG. 1. COMPARISON BETWEEN CHLORINE-ABSORBED AND OXYGEN-CONSUMED RESULTS (AVERAGE VALUES)

and 10.0 p.p.m. vary a great deal and, although in general the values increase, these increases are not proportional to the amounts of chlorine added. It would seem that, if the total organic content of a water is to be determined, even larger amounts of chlorine should be used.

Whether or not the 1.0 p.p.m. value is more indicative of bacterial content than of oxidizable matter is a question. The fact that a water may have a high bacterial count and yet be low in organic content could possibly explain how it may absorb more chlorine in proportion to the amount added with the 1.0 p.p.m. dose than with the 5.0 or 10.0 p.p.m. dose. This happened several times, as seen in table 3.

In studying any other factors to which might be attributed the cause of a wide variation in the results of the two methods, it was noticed that in some cases where the chloride content was exceedingly high the oxygen consumed ran up higher than was expected.

TABLE 3

Oxygen consumed and chlorine absorbed in relation to bacterial count

	SAMPLE	OXYGEN CONSUMED	CHLORINE ABSORBED			AGAR COUNT PER CUBIC CENTIMETER	FERMENTATION (LACTOSE 10 CC.)
			1.0 p.p.m.	5.0 p.p.m.	10.0 p.p.m.		
		p.p.m.					
1	Well	1.35	0.21	0.28	0.50	62	Positive
2	Well	1.40	0.30	0.45	0.66	10	Positive
3	Spring	1.47	0.32	0.50	0.92	100	Positive
4	Spring	1.95	0.28	0.35	0.60	400	Positive
5	Well	4.70	0.52	0.90	1.63	2000	Positive

TABLE 4

Oxygen consumed and chlorine absorbed in relation to alkalinity and to chlorides

	SAMPLE	OXYGEN CONSUMED	CHLORINE ABSORBED			ALKALINITY WITH M. O.	CHLORIDES
			1.0 p.p.m.	5.0 p.p.m.	10.0 p.p.m.		
		p.p.m.				*p.p.m.*	*p.p.m.*
1	Well*	1.35	0.21	0.28	0.50	3.1	Trace
2	Well*	1.46	0.20	0.44	0.85	4.0	Trace
3	Spring	1.15	0.40	2.39	4.21	177.0	42.5
4	Spring	2.10	0.61	0.95	1.10	128.0	12.5
5	Well	2.27	0.78	2.75	3.50	191.6	51.0
6	Well	2.72	0.50	1.25	1.32	68.0	10.0
7	Well	2.37	0.46	0.72	0.87	98.0	228.56
8	Well	4.50	0.58	1.30	2.30	105.0	102.58
9	Well	4.70	0.52	0.90	1.63	47.2	256.0

* Low in both alkalinity and chlorides.

On the other hand, some waters high in alkalinity absorbed an unusual amount of chlorine. These facts are shown in table 4.

This might be explained by the fact that more of the available oxygen is used in oxidizing the large amount of chlorides present. A water high in alkalinity might absorb more chlorine in the formation of certain hypochlorites.

In connection with the work which has been done, many data of interest have been gathered from Keiser's paper (4) in which he makes a comparative study of the two methods on raw Elbe water and the filtered water at Hamburg. Keiser's work was found in the literature after the investigation here had begun. His data might explain some of the variations observed here in comparing the two tests. A study of these results shows that, for the determination of organic matter in water free from albuminous products, the permanganate process according to Kubel and the determination of the chlorine number of Froboese are equally good; on the other hand the content of organic matter in water which has been polluted with sewage, can be exactly fixed only by means of the chlorine absorption test.

TABLE 5

Effect of urine content on oxygen-consumed and on chlorine absorbed

URINE CONTENT	OXYGEN CONSUMED	CHLORINE ABSORBED (10.0 P.P.M. ADDED)
mgm. per liter	*p.p.m.*	*p.p.m.*
Tap water	1.30	0.32
1	1.35	0.40
3	1.38	0.72
5	1.33	0.80
10	1.36	0.85
50	1.42	1.15
100	1.45	1.59
250	1.96	2.51

In confirmation of Keiser's work, the data indicated in table 5 show the results carried out here with increasing amounts of urine in tap water. The chlorine-absorbed and oxygen-consumed values were noted.

It is indicated here that albuminous products like urine are not readily attacked by permanganate, so it would seem that the determination of the oxygen-consumed value is inaccurate under such conditions.

According to all the data shown herein, the correlation between the two methods is good as long as no albuminous material is present. In the latter case the chlorine absorption test is the only safe criterion. In view of these facts the chlorine absorption method should be in all cases an equally desirable one to use and, in certain cases, it

certainly would be preferable. It seems entirely reasonable that a standard method of procedure should be established wherein the quicker ten-minute chlorine absorption test would be used as a substitute for, or at least a companion test with, the slower permanganate method of determining oxygen consumed.

REFERENCES

(1) Standard Methods of Water Analysis, 6th edition, p. 22–24 (1925).
(2) Wolman, Abel, and Enslow, L. H.: Jour. Ind. and Eng. Chem., 11, p. 211 (1919).
(3) Froboese, Victor: Arb. Reichsgesundheitsamte, 52, p. 211–22 (1920).
(4) Keiser, Karl: Gas und Wasserfach, 69, p. 65–69 (1926).
(5) Pecker, H.: Jour. Pharm. Chim., 18, p. 134–9, 167–77 (1918).
(6) Buswell, A. M., and Boruff, C. S.: Jour. Amer. W. W. Assn., 14, p. 384–405 (1925).

WATER PURIFICATION[1]

By Paul Hansen[2]

A paper on water purification for municipal purposes written fifteen years or more ago would have dwelt at length on the benefits of purification and would have had much to say about the losses from sickness and death that can be prevented by water purification. It would also have translated the losses from sickness and death into dollars and cents, as it was generally assumed that this would make the most urgent appeal to public consciousness.

All that has changed, and today water purification is established and accepted. Health must be protected as a matter of course and higher and higher demands are being made as to physical and chemical characteristics of water supplied to the consumers. The change can best be explained by saying that the public has learned to want better water. Probably this education has come about principally through the force of example of those cities that were among the first to install water purification works. At this point there entered as a factor a degree of municipal pride which caused the public to feel that its reputation was at stake so long as muddy water was pumped into the mains. In the final analyses, however, it is a development in the public mind of an appreciation of and a demand for a better product.

Along with this installation of water purification works, there has developed a demand for constantly increasing standards of quality, so that many water supplies which ten or twenty years ago were regarded as fully satisfactory are not so regarded at the present time. All cities with untreated water supplies which do not meet present day standards know that they must, sooner or later, install water purification works and it is primarily a matter of deciding upon the best plan and of arranging necessary finances.

In the light of the foregoing, it seems more appropriate to devote this discussion to advances and present limitations in the art of water

[1] Presented before the Canadian Section meeting, March 3, 1927.

[2] Of Pearse, Greeley & Hansen, Engineers, Chicago, Ill.

purification than to an argument in favor of the application of water purification. In speaking of water *purification*, filtration should be understood as constituting the main element in the process. Disinfection of water with liquid chlorine or by other means should be preferably referred to as *treatment*, inasmuch as its sole function is to remove organisms of disease. It does not improve the physical or chemical characteristics of the water, but rather it makes them worse. Moreover, the disinfection of unfiltered water is fraught with so many difficulties and uncertainties that it should be looked upon usually as an emergency, rather than as a permanent, method of water treatment. Sterilization as an adjunct to filtration is fixed and accepted and will be discussed later. Removal from water of minerals causing hardness and also the removal of iron and manganese which cause discoloration in water are also forms of water purification but these can be touched but lightly at the present time as each constitutes in itself a rather large intricate field or water treatment.

STANDARDS FOR FILTRATION PLANT PERFORMANCE

The most important development in connection with water purification practice which has taken place during the past quarter of a century is the increasing standard for measuring the performance of water purification works. In 1900 a reduction in bacterial content of 97 per cent (as determined by plating on nutrient gelatine at 20°C.) was regarded as adequate. Many of the filter plants of the country were installed by filter companies and they usually made guarantees of 97 per cent removal, provided the bacteria in the raw water were not less than 1000 per cubic centimeter. If less, then it was agreed that the number of bacteria in the filtered water should not exceed 100 per cubic centimeter. At a later period, efficiencies of 98 per cent were regarded as necessary and a maximum of 50 bacteria in the filtered water per cubic centimeter was set as a proper limit. There was also much discussion as to whether any analytical standards could be adopted. Many engineers and analysts maintained that epidemiological evidence constituted the only reliable guide and that any analytical data must be interpreted in the light of local circumstances. In 1911 and 1912 a committee was appointed by the United States Public Health Service to agree upon standards of analyses for drinking water used on inter-state carriers. This committee worked for three years before an agreement could be reached. However, the committee finally decided upon the now more or less familiar "Old"

Treasury Standard for drinking water on inter-state carriers. There was a great deal of opposition to the acceptance of this Treasury Standard as a measure of performance of filter plants. It became obvious, however, that with disinfection with liquid chlorine as an adjunct to filtration, this standard of purity was an attainable one and, inasmuch as high standards are in the direction of greater safety, it became generally accepted. In 1925 the Treasury Standard was revised. Although made somewhat stricter, it permits more latitude in variations in individual samples than did the Old Standard. It is now required that not more than 10 per cent of samples shall give positive presumptive tests for the colon bacillus in 10 cc. portions, equivalent to a coli index of 1 per 100 cc.

RAW WATER LIMITS

Another interesting development with reference to units of measure in connection with the performance of purification works is the consideration that has been given to the limit of pollution of raw water. This matter was first taken up by the International Joint Commission on Boundary Waters between the United States and Canada. The experts who were engaged by this Commission came to the conclusion, on the basis of the evidence available in the Great Lakes basin, that a raw water in order to be amenable to treatment by established and standard methods of water purification should not contain more than 500 colon bacilli per 100 cc. The limit of pollution was predicated on the purified water meeting the Old Treasury Department Standards.

In 1922 H. W. Streeter of the United States Public Health Service made a statistical study of the performance of twenty-five water purification plants in the central west on the basis of data previously collected by Jack Hinman and presented in THE JOURNAL for September, 1918. On the basis of relations thus established it appeared that the average efficiency of modern filter plants of the rapid sand type, supplemented by chlorination, is such that, in order to obtain a purified water complying with the Old United States Treasury Standard for purity of drinking water on inter-state carriers, namely a colon bacillus content of 2 per 100 cc., the raw water should not have an average colon bacillus content of more than 650 per 100 cc.

In 1923 Streeter made elaborate comparative studies of the performance of ten filter plants taking water from the Ohio River and confirmed his former studies showing a definite relation between raw

water bacterial content and filtered water bacterial content. At the plants studied, however, chlorination of the filtered water was necessary to secure a final effluent that would meet the Old Treasury Standard when the raw water contained colon bacilli to the extent of 100 per 100 cc. and even less. Where chlorination was used, filter plants with double coagulation and double sedimentation could adequately purify waters containing as many as 10,000 colon bacilli per 100 cc., while plants with single coagulation and sedimentation could successfully handle waters having materially in excess of 1000 colon bacilli per 100 cc.

Further studies on an experimental filter plant at Cincinnati have verified these findings and have indicated 100 colon bacilli per 100 cc. as the limit of raw water pollution where filtration alone is employed.

FURTHER AIDS TO CONTROL

Although not related directly to the measure of results obtained by water purification works, practical methods for the determination of hydrogen-ion concentration in water have proved very helpful in securing effective and economical application of coagulants.

Another aid to the control of a filtration plant is the microscopic examination of sand grains as developed by Baylis at Baltimore. The effectiveness of filtration and the general behavior of sand beds is intimately related to the thickness and character of organic coating surrounding sand grains. Experience in examining sand grains will indicate when corrective measures are required to prevent excessive cracking of sand beds and to prevent the formation of mud balls.

New methods of recording the sizes of sand grains in rapid sand filters are coming into vogue notably at St. Louis and Baltimore. Instead of considering the sand bed as a mass, it is considered as composed of layers and the size and uniformity of sand grains in each layer is considered. Further study of the performance of rapid sand filters, with reference to the stratification of the sand bed, should throw more light on the character and thickness of sand required to obtain best results. Present practice is based largely on precedent and generally accepted experience rather than on a close analysis of the functioning of the sand bed.

During the past ten years great improvement has been made in the general arrangement of filter plants with reference to ease of operation, accessibility of parts for repair, light and practical beautification.

The buildings and interior finish of filter plants is becoming comparable to the best pumping station practice. Some of the newest filters, notably the new Baldwin Filtration Works at Cleveland are veritable temples to pure water.

APPLICATION OF CHEMICALS

With reference to the preparation and feed of chemicals little notable advance has been made. There has been a tendency toward dry feed machines in preference to wet feed. In some cases, notably at Indianapolis, ingenious hydrometric devices have been developed for maintaining a solution of constant strength that may be fed into the water at rates proportional to the volume of water being delivered to the plant. Inasmuch as filter plants are usually operated at a fairly uniform rate, these elaborations have not been found altogether necessary. With small clear water storage these devices may prove valuable especially when operated in conjunction with master filter rate controllers. There are a number of dry feed machines on the market which now give good results. The early machines were troublesome, partly on account of clogging and caking of the chemicals and partly because they were not built sufficiently rugged. At Wheeling, West Virginia, there has recently been installed a machine for slaking and feeding lime which is economical of space and cleaner than the usual methods.

Much thought has been given to the design of mixing chambers for the purpose of mixing the chemicals intimately with the water to be treated, but there still remains more or less divergence of opinion as to the best design and capacity for these chambers. The tendency is toward a vigorous mixture immediately following the application of the chemical, followed by a gentle mixing for a more or less prolonged period. Some are inclined to believe that, if a thorough mixing is obtained promptly following the application of a coagulant, further mixing is unnecessary. This seems to be borne out by the behavior of the coagulant in some plants where complete precipitation does not take place until long after the water has passed out of the mixing chambers. Various methods are used for mixing the water such as baffles, stirring devices or a waterfall, exemplified in the hydraulic jump. Further study on this important item is desirable as there is at present a rather wide divergence in the design of reaction chambers.

SEDIMENTATION BASINS

Although sedimentation has long been regarded as an important part of rapid sand filters, the principles upon which sedimentation basins should be designed have never been adequately applied in practice. It is generally assumed in modern practice that a retention period in sedimentation basins of two hours represents a minimum and that more is desirable depending upon the amount of turbidity carried by the water. There seem to be other factors that should enter into a consideration of the size of sedimentation basins, including the time required for precipitation of chemicals under adverse conditions and the treatment of raw water with chlorine when split chlorination is used or when super chlorination is deemed advisable for killing troublesome organisms or overcoming phenol tastes. Although Hazen, in 1904, laid down some important principles in regard to the design of sedimentation basins, these have not generally been regarded. The controlling elements in actual practive are primarily economy of shape and ease of construction. This generally results in the installation of basins much deeper than is necessary for storage of settled solids and for producing most favorable sedimentation.

Withing the last few years much attention has been given to the use of mechanical devices for continuously cleaning sedimentation basins used for waters carrying excessive turbidities. Such basins are being incorporated in the new works at Kansas City. Basins of this type may be used before or after the application of the chemical coagulant.

Very favorable results have been noted in the Ohio River valley as a result of the use of double coagulation and double sedimentation. This not only makes it possible to handle more pollution, as already indicated, but also improves the economy of chemical application.

FILTER UNITS

There has been comparatively little change in the design of the filter units themselves. Units built during the past year have not differed essentially in size or arrangement from those built twenty-five years ago at Little Falls, New Jersey. Principal attention has been given to the underdrain system. Within the past few years a number of new devices have been proposed. Gore of Toronto has effectively prevented the shifting of the gravel bed by mixing the

upper layers of the gravel with a thin cement so as to form a porous slab. This idea has been extended further by Jenks in Sacramento, who proposes a strainer system consisting of vitrified pipe imbedded in gravel held together with thin cement in the manner used by Gore. Experimental results on the Jenks type of filter bottom are very favorable. They would probably give trouble, however, if used in connection with a water softening plant or a plant in which lime and iron are used as coagulants on account of the tendency of the material to clog with deposits of lime. Delerey of New Orleans has patented the use of brass tube laterals of relatively large size and perforated with a special type of opening which tends to neutralize the effect of velocity head in forcing the larger portion of the water to the outer ends of the laterals. Several of the filter companies have gotten out various schemes for cement block underdrain systems one of which uses glass tubes for openings. At Baltimore wooden slat underdrains have been tried and seem to give successful results. Most of the efforts in connection with the design of underdrains have been toward economy rather than improvement in the functioning of the underdrains, inasmuch as it has been found in practice that a properly designed system of underdrains consisting of a grid of piping with perforations on the underside of the lateral piping gives reasonably good results in the distribution of wash water. The most conspicuous change over earlier practice is the virtual abandonment of brass strainer heads. Twenty years ago every filter company had its own design of strainer. Some engineers also designed special strainers. These gave a great deal of trouble by wearing out, due to the abrasion of sand and often the threads which attached them to the lateral pipes became corroded so that they were blown out resulting in very bad distribution of wash water and much sand getting into the effluent piping.

Filter units are built in a number of sizes, the most usual encountered in practice being one-half million gallon units, one million gallon units, two million gallon units and four million gallon units. Occasionally there are odd sizes. The variation in size is somewhat controlled by the variation in size of standard piping and valves. Four to six million gallon units are generally accepted as the maximum size units practicable. It may be possible to build larger units, but they would be of questionable economy because of increasing elaboration in the design of the underdrain system and wash water troughs for the purpose of getting equal distribution of wash water.

CLEAR WATER BASINS

Clear water storage reservoirs have changed but little in design. It has been universally accepted that they must be covered to prevent accidental or malicious pollution and the direct entrance of sunlight which promotes the development of chlorophyll bearing plants. Little uniformity of practice exists in determining the size of clear water storage. It has varied over a wide range. More recently, especially in connection with the larger installations, more thought has been given to an economical and workable balance between filter capacity and clear water storage capacity. There are a number of factors that enter into a consideration of a proper relation between clear water storage and filter capacity. An economical balance between filter capacity and clear water storage may be arrived at on the following basis. The filter capacity is generally made sufficient when operating at maximum rates (anywhere from $1\frac{1}{4}$ to $1\frac{1}{2}$ times normal rates) to yield the quantity of water anticipated on a maximum day likely to occur in the last year of the period for which the plant is designed. Either storage or additional filter capacity is required to meet the differential between a variable rate of consumption and a uniform rate of filtration throughout the twenty-four hours, plus an added quantity for washing filters and a sufficient reserve to meet reasonable fire demands. The quantity of water required for neutralizing the differential between the variable rate of consumption and the uniform rate of filtration can be determined by means of a mass diagram. Curves showing the cost of storage of various capacities and additional filter capacities can be drawn in such a way as to show the economical balance. A decision cannot be made on the basis of economy alone, but an analysis as above outlined furnishes a valuable guide to judgment. It is quite important to consider convenience of operation. If there is but very little clear water storage and large filter capacity, it will be necessary to vary the rate of delivery of raw water at frequent intervals during a day of maximum or nearly maximum consumption. If the raw water must be pumped, this requires increased pumping capacity and a larger number of units with attendant bother in operation. Some inconvenience also results in the application of chemicals, to meet varying numbers of filters in service, but this can in large part be overcome by automatic devices already referred to.

If an elevation is available upon which reservoirs may be cheaply

placed and connected with the distribution system, additional storage may be economical and desirable to improve high lift pumping conditions. Large storage on the distribution system is particularly valuable when pumping is done by purchased electrical energy. Under this condition the pumps can operate at their maximum efficiency, the demand charges for electricity are cut down and standby equipment using an independent source of power may be maintained at a minimum or even omitted altogether.

AERATION

Aeration has been extensively used as an adjunct to filtration, usually preceding the application of chemicals. In recent years consideration has been given to aeration following filtration as a means of eliminating carbon dioxide and any tastes and odors that may have escaped preliminary aeration and filtration. A variety of aerators have been used, some involving an arrangement whereby the water can fall over a series of steps, others using spray nozzles similar to those for cooling condenser water and still others using diffused air either blown into the water or entrained in some manner. Nozzles are most favored, although these require a considerable pressure of water to make them function properly. Nozzle design has been improved in the past year or two so as to minimize the head necessary to secure a good spraying of the water. Aeration is found very effective in removing certain forms of tastes and odors, more particularly those resulting from microörganisms. At Whiting, Indiana, the aerators were found effective in removing odors due to oily wastes from oil refineries, but were not effective in removing phenol tastes and odors. Aeration is applied to ground water for removing hydrogen sulphide and for oxidizing and precipitating iron in solution.

DISINFECTION

Chemical treatment of water for various purposes has been given much thought in recent years. The outstanding chemical treatment is by means of chlorine. Ten to fifteen years ago disinfection was effected primarily with calcium hypochlorite rather than with chlorine. The application of liquid chlorine was introduced by Darnall in 1910. Apparatus for applying liquid chlorine or chlorine gas has been constantly improved by manufacturers, so that chlorine application can now be readily adapted to meet almost any needs.

Chlorine may also be used effectively for reducing tastes and odors, notably phenol tastes. In order to accomplish this, super-chlorination is required, that is, to say a dose of chlorine much larger than that required for sterilization must be used and one which results in imparting a marked chlorine taste and odor. This excess chlorine must be neutralized and for this purpose sulphur dioxide in cylinders has been found the most practicable and effective as used by Howard at Toronto. Thiosulphate and potassium permanganate can also be used to neutralize excess chlorine, but these chemicals are more expensive. Filters sometimes give trouble, especially in iron removal plants due to clogging with organisms—more particularly crenothrix. Not only does crenothrix clog the filters, but it also creates objectionable tastes in the water. Pre-treatment with chlorine has been found effective in combatting crenothrix. Its success with other organisms has thus far not been so pronounced, although Hale accomplished notable results in treating the Croton water supplying New York City. The waters of Lake Michigan and other great lakes are particularly troublesome at certain times due to the presence of large numbers of microörganisms. These organisms are apt to occur when the water is most clear and in mid-summer. In some places, notably at Evanston and Winnetka, Illinois, organisms have been known to clog filters, thereby reducing filter runs to two or three hours. Opportunity has not yet presented itself for an effective test of chlorine in combating this difficulty.

Pre-treatment with chlorine, or so called split chlorination has also been found effective in reducing the amount of coagulant required. The nature of this action is not entirely clear, but has been observed at several plants, notably at Rensselaer as reported by Cox. The use of ammonia with chlorine or hypochlorites to produce chloramine as introduced by Race at Ottawa is receiving new attention as a means of combatting or avoiding residual chlorine tastes.

OTHER CHEMICAL TREATMENT

The use of lime and soda ash and zeolites for softening water will not be discussed in this paper. It may be well to note in passing, however, that the use of carbon dioxide usually generated at the purification plant is used for treating the softened water so as to remove mono-carbonates which tend to encrust sand grains and deposit in the distribution mains. Back treatment with carbon dioxide is also advantageous at plants not primarily devoted to water soften-

ing, but where lime and sulphate of iron are used as coagulating chemicals.

Corrosive qualities of water have been given considerable attention in the last few years. Filtered water in connection with which alum is used as a coagulant is apt to contain excess of carbon dioxide and oxygen which tends to tuberculate and corrode piping, especially hot water piping. This difficulty is being met in part, as already noted, by aeration following filtration and in part by lime treatment following filtration. Lime treatment need not be carried on continuously, but merely until a protecting coating has been formed in the distributing piping. This coating requires renewal from time to time. Lime treatment for this purpose has recently been instituted at Centralia, Illinois with marked success. Use of sodium aluminate as a coagulant also has a distinct advantage in eliminating the corrosive qualities of filtered water and favors quick flocculation.

MEASURING AND INDICATING DEVICES

Filter plant control has been improved by more complete measuring and indicating devices than were formerly customary. In plants of larger size, it is usual to meter the raw, the filtered and the wash waters. Large dials readily seen from any part of the plant as used at Buffalo are helpful in enabling the attendants to observe the rate of flow of water. Individual filters are equipped not only with indicating loss of head gages and indicating flow gages, but also with recording equipment so that charts may be maintained of the daily performance of every filter unit.

DETERIORATION OF CONCRETE

When reinforced concrete filter plants were first built, there did not exist an appreciation of the tendency of concrete to disintegrate in contact with water due to leaching out of soluble matters supplemented by frost action. This action has been aptly termed by Bayliss the "corrosion of concrete" and is a phenomenon observed most frequently at and above the water line, although as at Baltimore and elsewhere it has been known to take place below the water line. The principal cause of disintegration of concrete is apparently porosity. Porosity is particularly destructive of walls holding water on one side and exposed to frost action on the opposite side. Such walls are frequently used in connection with filtration plants. Within re-

cent years a realization has come about of the importance of securing the densest possible concrete and this can best be accomplished by maintaining a proper cement water ratio. Many engineers now specify cement water ratio mix for concrete for all classes of concrete. This was done in connection with a recently completed reservoir for the Indianapolis Water Company at Indianapolis and proved to be entirely practicable and successful. To avoid further the disintegration of concrete, consideration is being actively given to the use of waterproofing compounds. These compounds are not used primarily for the purpose of making reservoirs water tight, but are applied at and above the water level in order to provide a surface impermeable to water.

INCREASING RAW WATER LOADS

Although not within the category of water purification, the question of sewage treatment as a means of preventing too great a burden on water purification works has recently been more or less discussed. It is undoubtedly a question which will become more and more prominent in the near future. Needless to say, sewage treatment of any type cannot be regarded as a substitute for water purification, not only because it would be ineffective as such, but because sewage treatment costs more than water purification per capita. The most logical and equitable manner of approaching this question is not entirely clear. There is at present a tendency to demand that degree of purification of sewage which will maintain the water in a stream at points where it may be used for water supply within the tentative limit of pollution established by the International Joint Commission on the Pollution of Boundary Waters, and by the United States Public Health Service, namely a maximum of 500 colon bacilli per 100 cc. of water. It may be found impracticable and prohibitively expensive in some cases, especially below very large cities, to maintain such a degree of purity in waters, nor may such a degree of purity be necessary to meet other requirements of sewage disposal. To meet situations of this sort it may be necessary to envisage the possibility of more water purification. The studies of Streeter along the Ohio River indicate that an elaboration of water purification works may effectively meet added pollution. For example, a water purification plant comprising double coagulation, double sedimentation, rapid sand filtration followed by slow sand filtration, split or super-chlorination and other accessories may readily purify water containing

50,000 and more colon bacilli per 100 cc. This suggests the possibility that slow sand filtration may be revived as a secondary process to rapid sand filtration for which it would be peculiarly well adapted. It is actually being used in this manner in several places, notably at Poughkeepsie and Albany, New York. Double filtration is also used at Montreal, but not in the same manner as here suggested, inasmuch as the rapid sand filters at Montreal are not preceded by coagulation and sedimentation. The limit to which water purification can be carried is not entirely clear. It is probable that before pollution reaches the limit of what an elaboration of water purification processes can effectively handle, the aesthetic sense of the water users will rebel and demand either more sewage treatment or the development of a source of supply less subject to contamination. This latter alternative is exemplified in the case of Albany, which, after establishing a plant comprising an unusual elaboration of water purification devices, is now seeking at large expense a water less subject to pollution than is the Hudson River below Troy.

It would seem desirable, where practicable, to correlate sewage treatment and water purification along a given stream. Generally, this is not practicable as municipalities are not disposed to purify sewage at great expense in order to protect water supplies below, unless forced to do so through legal pressure. There has recently been created in Illinois machinery for handling such a situation in the form of a Conservancy District Act, under which water supply and sewage disposal may be placed under the control of a central authority for an entire river basin or any portion thereof. Lake cities which pollute their own water supply with their own sewage have the opportunity of working out an economical balance between water purification and sewage treatment. It often happens, however, that matters other than water supply, namely, the prevention of nuisance and the protection of bathing beaches, determine the necessary degree of sewage treatment. However, the opportunity does exist in a number of instances and is worthy of much thought and investigation on the part of sanitary engineers. In the North Shore Sanitary District of Illinois, for example, the most economical sewage treatment for the protection of water supplies and bathing beaches has been found to be sedimentation followed by chlorination. These plants are relatively small in size and a quite different solution might be required where large volumes of sewage are being dealt with.

In conclusion, it is desirable to point out that, notwithstanding the

relatively wide field for the further development and perfection of water purification processes, the art of water purification has long been developed to the point where water purification problems of cities may be solved with economy and absolute assurance that the results will be satisfactory. The further development of the art relates primarily to refinements in control, to perfection of construction details, to the better use of construction material, to broadening the field of applicability of water purification processes and to the co-ordination of sewage treatment and water purification.

DRAMATIZING WATER WORKS REPORTS[1]

By J. R. Cortese[2]

Some water works superintendents, and occasionally city officials, may question the value of a water works report and doubt if its cost is money well spent. The answer to this question is simple. It depends upon the report.

One of my favorite indoor sports is to examine water works reports: the good ones being read with much interest and filed for frequent reference.

Water works reports reflect exactly what the superintendent or manager is. Invariably a good superintendent issues a good report. When one examines, as I have recently, a report that contained page after page of fire hydrant locations, and another report where pages were devoted to statistics fifteen to twenty years old, it does not require an efficiency expert to figure out the loss and waste of time and money by issuing such a document. The printer's proof reader was probably the only person who read the entire document. My criticism of water works reports comes from reading them and, therefore, from the standpoint of the consumer, I am going to mention briefly a few features of reports that have made them especially interesting to me.

WHY SHOULD A REPORT BE MADE?

A water plant is one of the chief assets of a city; in value it ranks well towards the top of all the city investments, whether owned by the city or company. The success and continued operation of all other industries, factories, etc., are dependent entirely upon the water works. The health, growth and prosperity of the city are entirely dependent upon the purity and cleanliness of its water supply. Its customers extend over the entire city; its commodity is standardized and is of one quality. If the city owns the enterprise, every citizen of the town is a stockholder and, therefore, a report to the public

[1] Presented before the Montana Section meeting, January 8, 1927.

[2] Superintendent, Water Department, Livingston, Mont.

is due; and the public, further, has a right to demand a real water works report in keeping with the importance of the utility.

APPEARANCE OF REPORT

Reports, like people, are often judged by appearances and, therefor, it should have an attractive cover and be of a good quality of paper and printing. Like a girl's skirt, it should be long enough to cover the subject, yet short enough to be interesting. The pictures accompanying a magazine article always produce a desire to read the article and photographs and cuts should be freely used to relieve the monotony in text statistics.

WHAT IT SHOULD CONTAIN

A brief historical sketch, giving date of purchase or date when built and the present value of the property, is always of interest to new customers.

Statistics themselves are rarely read by the layman and these should be converted into graphical diagrams, which are understood at a glance.

A concise tabulation of operating costs, annual revenue, fuel costs, increase in number of connections, etc., shown both by figures and graphical charts, are always interesting and these should not cover more than a ten-year period, as old statistics are of little interest or value.

A population curve and water consumption curve are always well worth the making, as it shows what future provision for growth should be made.

A plain statement from health authorities regarding purity of water, with percentage of bacteria removed, with cuts or illustrations of bacterial comparison of raw water and treated water, is the best kind of advertising a report can contain, for one must not forget that his business is selling water and the reports help sell the customer. People always like to know how their money is spent and a graphical diagram showing what part of a dollar goes for interest, labor, fuel and operation, is enlightening.

Illustrations showing losses by leaky faucets, bad plumbing and unregulated flush tanks for sewers, are helpful in bringing about reforms. Such illustrations are convincing in showing customers how much their own bills could be reduced by eliminating all wastage.

The reduced pumpage, fuel or power bills and increased revenue by a universal meter system are features that can and should be shown in every water works report, for even in this enlightened day we find a few communities who still sell, or rather give water away, without meter measurement. Our city of Livingston happens to be one of them, but we hope that within a year or two we will be metered.

The city, corporation or individual does not exist that can make a success of selling any commodity without measurement of the amount sold. The report should show, or account for, the loss between water delivered and water sold, and if this does not show a yearly improvement, something is radically wrong and needs correction.

A water works plant is never finished or completed and the needed extensions, betterments and improvements ought always to be prominently shown in a report, then there are no shocks or surprises. If bonds are needed there is nothing gained by concealing the fact. Show in the report why the improvements are needed and what advantages and results will be gained by them.

Every report ought to show the cost of delivering water per 1000 gallons, including interest, depreciation, sinking fund reserves, etc. This information is not always known by the superintendent himself and when he figures it out, he will, in many towns, find that large users, railroads especially, are getting their water at less than its cost of production. When one glances at his own railroad and Pullman expenses these times, it causes the reflection that railroads ought to have sufficient funds available at least to pay for the cost of furnishing water. In these days of regulation of rates, one cardinal law acknowledged by all is that the rates of each utility, whether a water plant, light plant, or railroad, should be based on its value and cost of operation. The railroads or other large users are not institutions, with rates made because of their being a special aid or help to a town. Every report should show what the rates should be to earn this interest, depreciation and operating expenses.

VALUE OF A REPORT

A report is of much advertising value to the entire community, so much so that many commercial clubs are joining in the expense of printing and circulating water works reports. Every live water works superintendent knows the advertising value himself of getting out a good report. It places him in a favorite light before many other communities where opportunities for advancement exist.

The educational value is of greatest importance. It acts as an aid in getting bonds for needed improvements, as a basis for argument for equalizing rates or in securing a raise of rates.

HOW PRESENTED

A report to be of any value must be interesting, for if not interesting it will never be read. The author of the report or some water works official should personally present a resume of his report before every civic organization of the town, not omitting the women's clubs. These reports, thus presented, keep before the public a keen interest in their own utilities. Extracts from reports are desired by the local papers and should be given to them. Exchange your reports with the official of other cities of your state.

The water works plant is the chief asset of the city, but the lack of general knowledge concerning it is a fault we can largely correct by getting out and presenting a genuinely interesting report. Whether it pays or not depends on the report and its presentation.

WATER RATES[1]

By J. Clark Keith[2]

The average citizen pays less than one cent per day for practically an unlimited supply of water. From the waterworks department he secures the cheapest service rendered by any public utility, while at the same time immediate and insistent complaint arises if the service is suspended even momentarily. It is rather taken for granted that interruptions in electrical or gas service may arise from time to time and little, if any, comment is made, but a waterworks distributing station is expected to be the nearest approach to perpetual motion that has yet been devised.

The growth of any water supplying organization, either municipal or private, is dependent upon and presumably keeps pace with the municipal demand. From humble beginnings it extends its service where and as required and, like all other businesses, the service which it can render is dependent upon the return secured for that service. The method of obtaining revenue is as peculiar to each community as is the design of its pumping station or the layout of the distribution system. Rates which would create a surplus in one community would be disastrous in another, with conditions seemingly parallel. In dealing with public utility corporations, the courts have excluded evidence tending to prove the worth of the service to the users, by a comparison of the existing rates with the charges for similar service in other communities. This is based on the fact that identical plants rarely exist in two places and weight cannot be given readily or intelligently to the different causes which tend to make the cost of the service, or worth of the service, more in one plant than in another. Under equally efficient management, there is a definite reason why water in one community costs more or less than in another which appears similar and the price of service is not susceptible to yardstick measurement.

[1] Presented before the Canadian Section meeting, March 4, 1927.

[2] Chief Engineer, Essex Border Utilities Commission, Windsor, Ont.

THE DETERMINATION OF RATES

It will be accepted as an axiom that, before it is possible to determine rates on any basis whatever, the cost to render service must be definitely known. Equally important is an accurate knowledge of the quantity of water pumped; displacement measurements are a delusion. Mature consideration is too frequently lacking in the building of a rate schedule which will create the necessary revenue and at the same time distribute it according to benefit. The cost of the plant is the first element involved and includes all expense of every character whatever up to the moment when the plant is ready for operation. Repairs, renewals, replacements, additions and betterments are the natural outcome of placing the plant in service. In private companies, the elements of franchises, good will and value as a going concern are attributes of value, inherent in a live plant. While such companies may or may not recognize those elements in their rate structure, they have a very tangible and recognized value where appraisals are being made for purchase. There should be sufficient revenue to give a fair return on the outstanding bonds or to retire debenture indebtedness; to meet the annual cost of operation; to provide a depreciation reserve for contingencies or for certain elements which may need replacement within their bonded life and to provide a working cash balance to reduce bank borrowings to a minimum. The creation of sinking funds in municipal practice is largely giving place to equal payment serial debentures and is eminently more satisfactory.

It is as essential in municipally owned waterworks that accurate information be available on which a rate schedule is to be based as it is in a privately owned company, which, in addition to giving adequate service, must show a profit for its shareholders. Without this information, a healthy plant condition cannot be maintained or equity be established as between consumers. With a high type of accounting, much statistical information of infinite value to the waterworks field would be made available, whereas much that is now available is not only misleading but inaccurate.

FIRE PROTECTION CHARGES

The vital question of fire protection charges rarely receives the analysis that it deserves. Since the investment for fire protection may represent 50 per cent of the total plant cost, depending on the

size of the municipality, it becomes the most important matter in the making of the rate schedule. There seems to be an undercurrent of opinion that a charge of about $35.00 per hydrant represents a fair return for fire protection benefit, while in fact there is no more justification for this than to assume that 10, 20 or any number of cents is the proper charge to be made per thousand gallons for water. The municipal council which will willingly assume for a community its fair and just proportion of this charge appears to be yet unborn. A fair fire protection charge has its proper place in the general tax, but rather than incur public criticism due to a rising mill rate, the line of least resistance is through the waterworks department, resulting in a water rate that is not equitable. Nor should the waterworks department be called upon to furnish "free" water to other civic departments or to civic institutions. Because certain public undertakings enjoy exemption from taxation conferred by the Legislature and over which municipal governments have no control, it does not follow that municipal councils should become generously philanthropic at the expense of the water department. The function of a water department is to distribute water, not to dispense charity.

The law does not prevent a municipally owned system from operating at a profit as a separate source of municipal revenue, if it is disposed to do so. Such operation may favor the owner who does not take water in proportion to the value of his property. On the other hand, if the plant is operated at a loss with a deficiency secured through the general tax rate, the water consumer is then favoured at the expense of the taxpayer.

The determination of the revenue for fire protection should not be secondary to that which is received from other sources, and each must be considered in relation to the other. The question of fire protection is the subject matter of another paper today and it will be assumed that the revenue to be derived from this source has been determined prior to the definite and final establishment of other rates.

READY-TO-SERVE EXPENDITURES

The service rendered by a water distribution organization is twofold. It must be prepared to serve a customer when service is asked which involves a definite capital outlay for pumping equipment, buildings, reservoirs, distribution mains and incidentals. This ready-to-serve expenditure is necessary regardless of the quantity used and

a reasonable charge for this service should be unquestioned. When a service connection is made there is an unwritten guarantee from the organization that water will be forthcoming whenever a demand is made in the system. When this occurs, an expense of an entirely different character is incurred. There is an outlay for labor, fuel, power and sundry other items. This is the cost of delivering the service which has been previously guaranteed and for which a charge may be made on the basis of the water actually supplied.

A minimum rate payable by each individual service connected to the distribution system regardless of whether or not any water is used has been shown by experience to be a necessity. Each service connection represents a certain portion of the total cost of the system and should naturally bear its share in the total cost of operation and maintenance. If half of the domestic consumers pay for water on the minimum rate basis, as is sometimes the case, it is apparent that unless the minimum rate is high enough, the revenue derivable from such sources is not commensurate with the cost of producing the service. In 1918, Allen Hazen, in "Water Rates for Waterworks" stated "Minimum rates are used by a great majority of waterworks systems. The service charge is being adopted in many rate schedules, but has not come into general use." Five years later the American Waterworks Association adopted a standard rate schedule recommending the service charge in preference to the minimum rate.

DIVERSITY IN RATE SCHEDULES

There is a wide diversity in the method of the collection of water rates in Canada. They naturally divide themselves into two classes; flat rates which involve any number of factors in their determination —assessment, frontage, floor or lot area, number of outlets, rentals, persons in the household—any method except sale by volume into which the second class falls. In the Canadian Municipal Index for 1926 there are 425 waterworks systems listed, of which 64 are private, 357 municipally owned and 4 controlled by the Dominion Government. Statistics of Canadian waterworks are very incomplete and those which follow were compiled from information contained in the Canadian Engineer of March 9, 1926. Figures given on 235 municipalities in tables 1 and 2 represent conditions in approximately 50 per cent of the systems in Canada.

From these tables it is apparent that the per capita consumption trend is upward with the size of the community; the per cent of serv-

ices metered, both industrial and domestic, increases with the population; 55 per cent of the communities have not any domestic meters installed; the domestic services of 70 per cent of the communities are

TABLE 1

Waterworks statistics of Canadian municipalities

POPULATION (CLASS)	NUMBER OF MUNICIPALITIES	AVERAGE POPULATION	PERSONS PER SERVICE	PER CAPITA CONSUMPTION	PER CENT OF SERVICES METERED		100 PER CENT METERED			
							Domestic		Industrial	
					Domestic	Industrial	Number	Per cent of total	Number	Per cent of total
				gallons						
0– 10,000	178	3,650	5.0	109	14.7	60.0	25	14	90	51
10,000– 25,000	36	15,100	4.9	124	24.9	78.1	4	11	23	64
25,000– 50,000	10	31,550	4.8	79	48.6	97.0	1	10	9	90
50,000–100,000	5	63,100	4.9	131	74.0	100.0	3	60	5	100
100,000 up	6	209,000	4.6	139	Accurate figures not available				6	100
	235									

TABLE 2

Data on number of metered services in Canadian municipalities

POPULATION (CLASS)	NUMBER OF MUNICIPALITIES	PER CENT OF SERVICES METERED											
		Unmetered		1–25		25–50		50–75		75–99		100	
		Domestic	Industrial	Domestic	Industrial	Domestic	Industrial	Domestic	Industrial	Domestic	Industrial	Domestic	Industrial
0– 10,000	178	105	41	18	12	6	9	11	21	13	5	25	90
10,000– 25,000	36	19	3	5	2	3	1	1	5	4	2	4	23
25,000– 50,000	10	3	0	1	0	1	0	1	1	3	0	1	9
50,000–100,000	5	0	0	1	0	0	0	1	0	0	0	3	5
	229	127	44	25	14	10	10	14	27	20	7	33	127

less than 50 per cent metered; the industrial services of 70 per cent of the communities are more than 50 per cent metered and 55 per cent of the communities are fully metered industrially. If any conclusion

may be drawn from averages, it might be deduced that the majority of those who are responsible for the policy of rate collections in those plants favor some system other than by meters.

In every waterworks system, engineering science, either elementary or advanced, plays some part. Is it possible, in determining rates to employ methods which verge on the scientific? How many equations involving assessment, frontage, house area, rental value, bathtubs, and family averages are necessary to determine X, where X equals the numbers of dollars which constitute a fair price to pay for service? There must be some happy combination of these factors, as 22 cities in table 2 collect all their domestic rates by one or other of these means, while the revenue of 4 only is derived on a metered basis. If their method of application is susceptible to refinement it should be equally applicable to industrial use. It is found, however, that 11 of these 22 cities completely meter all industrial services.

The complexity of a charge for water on an unmetered basis is illustrated in the meter ordinance passed by Chicago in 1925, an extract of which follows:

> The minimum amount to be charged for water to any unmetered premises ranges from $3.50 for a building with a frontage of less than 15 feet to $20.00 for a frontage not exceeding 87 feet. For each story in excess of one story, an additional charge of $1.50 per annum shall be made. For each and every person in excess of twelve occupying any private residence, flat or apartment, an additional charge of 50 cents per annum is made. For each hose connection add $2.00.

While the installation of meters to insure equitable rates is commendable, it must be proven in addition that they will be an economic benefit. As an investment a meter must save enough to pay for depreciation and interest on the investment. The outlay will be about $20.00 per dwelling service. With a fifteen-year life there will be a depreciation of 6 per cent and on the basis of a 6 per cent return, the annual charge will be $2.40. Increasing the meter life to 20 years reduces this by only 10 cents. Meter reading, billing and collecting will account for $1.50 per service and the repairing and testing of meters not properly chargeable to the consumer may cost 60 cents. The installation of a meter thus imposes a total annual cost of $4.50 per domestic service. In table 3 the average cost of water per 1,000 gallons is shown to be 38 cents, at which price it would require the meter to effect a saving of 12,000 gallons annually.

A pin hole leak in a washer, not badly worn, will account for 45,000 gallons per year. There is thus a fair possibility that a meter will justify its installation. To meter or not to meter is not pertinent to the subject matter of this paper, but if and when a policy of metering has been decided upon, the question of rates must have been under consideration at the same time.

Meter rates per 1,000 gallons vary from 5 cents in a small community in Ontario to $3.00 in a town in Saskatchewan. One community in Alberta quotes a price of 15 cents per barrel, while one in British Columbia uses the United States gallon.

As a result of a survey carried out by "Waterworks Engineering" to ascertain the merits of the cubic foot or gallon readings, the following conclusion may be drawn. Most of the meters already sold read

TABLE 3

Metered rates in Canadian municipalities according to population

POPULATION (CLASS)	NUMBER OF COMMUNITIES	AVERAGE MAXIMUM RATE PER 1000 GALLONS
		cents
Less than 10,000	113	42.7
10,000– 25,000	29	30.1
25,000– 50,000	9	28.0
50,000–100,000	6	23.4
More than 100,000	6	17.0
Total.....	163	
Weighted average.....		38.0

in cubic feet. This is not so much an indication of present day practice, as it is a survival of the system in vogue years ago. The tendency is favorable to the gallon and the movement is rapidly spreading. Some cities calibrate their meters one way and sell water by another scale of measurement. The average water consumer has some idea of the quantity represented by 10 gallons; talk to him in cubic feet and it is a language he does not understand.

The rates for 1916 were taken from "Water Works Statistics of Canada" published by The Commission of Conservation and do not represent 25 per cent of the systems in Canada. From figures compiled by "The American City" in 1925, the average highest meter rate per 1,000 gallons in the United States is 33.9 cents, ranging from a state average of 7.3 cents in Utah to 97.5 cents in Arizona. The

average best commercial rate is 14.1 cents ranging from 6 cents to 29.5 cents in the same two States. In Canada the average best commercial rate is given as 10.6 cents.

While the figures in table 4 represent conditions in only a small proportion of the plants in Canada, they are sufficient to indicate that rates have not kept pace with the increased price of commodities entering into the cost of delivering water. The average price of cast iron per ton for the period 1911–1916, f.o.b. New York, was $28.51, while it averaged $57.52 for the decade 1917–1926. The price in Canada would be $8.00 per ton additional, plus freight and sales tax.

TABLE 4

Comparison of meter rates in Canada

PROVINCE	NUMBER OF COMMUNITIES	MAXIMUM AVERAGE METER RATE PER 1000 GALLONS		PER CENT	
		1916	1926	Increase	Decrease
		cents	*cents*		
Prince Edward Island	2	30.0	30.0		
Nova Scotia	10	21.3	25.6	20	
New Brunswick	5	21.0	28.0	33	
Quebec	9	28.0	27.0		3
Ontario	45	24.0	27.3	14	
Manitoba	9	36.6	58.0	59	
Saskatchewan	10	57.0	74.5	31	
Alberta	8	55.6	37.4		33
British Columbia	5	30.0	25.0		16
Total	103				
Weighted average		31.1	34.1	9.7	

From "Contract Record" the figures in table 5 have been secured showing the trend of materials and labor since 1916.

While open to correction, it is doubtful if any waterworks operating in Canada has raised its rates 50 per cent since 1914, unless due to some special cause such as the construction of purification works.

UNIFORM MINIMUM RATES

A minimum amount is collected no matter how small the consumption may be. The minimum rate charge is in use in most communities and may be used either in connection with a uniform rate or any

one form of sliding or step charge. The service charge is absorbed in the minimum charge. The average yearly minimum charge paid in the United States is $10.10, varying from a state average of $4.80 in North Dakota to $24.00 in New Mexico. In Canada the average yearly minimum charge is $9.71.

GRADUATED MINIMUM RATE

In this form of rate, the minimum charge increases with the size of the meter. One of the most potent arguments for a minimum rate

TABLE 5

Price trends since 1916

YEAR	WEIGHTED AVERAGE OF 32 BUILDING MATERIALS	IRON AND ITS PRODUCTS 26 LINES	INDEX NUMBER OF RATES OF WAGES IN BUILDING TRADES
1913 Base	100.0	100.0	100.0
1916	103.8	151.8	102.4
1917	130.7	220.2	109.9
1918	150.5	227.3	125.9
1919	175.0	201.8	148.2
1920	214.9	244.4	180.9
1921	183.2	185.7	170.5
1922	162.2	151.8	162.5
1923	167.0	168.0	166.4
1924	159.1	161.1	169.7
1925	153.7	152.3	170.4
1926	149.1	145.2	172.1
Average since 1916.....	159.0	182.5	152.6

charge is in the fluctuating demand over the day in almost any plant In the City of Windsor municipal system the peak load is 32 per cent above the average, while in that operated by the Walkerville Water Company the average is exceeded by 46 per cent. Under extreme weather conditions these percentages will increase, which would be typical of the average plant. There is no information available to show that demand meters in waterworks operation have ever been advocated as is common practice in the electrical field. Rates are based and revenues are derivable from average and not from peak loads and, where every service constitutes a potential demand on the system, a minimum amount should be collected. As an instance of this, a

manufacturing plant connected to one of the above systems, but having a private supply heavily chlorinated for plant use, switched without notice last summer and made a million gallon demand in less than twenty-four hours. The peak loads in most systems are, in the main, caused by general use spread over all consumers and where 50 per cent additional plant capacity is necessary as a safe working margin, those for whom it is available should expect to pay a minimum amount.

SERVICE CHARGE

This is a fixed charge made in addition to a charge for water. It increases with the size of the meter or service connection.

SLIDING SCALE

This scale may be used with or without the minimum rate or service charge and includes all cases where a varying rate is charged according to the quantity of water used. This plan, with a minimum charge, is in most common use. The type of sliding scale generally used provides that the water used to a certain limit is charged at a certain rate and additional quantities are charged at lower rates, but the higher charge on the first quantity remains a part of the bill.

THE MILWAUKEE RATE SCHEDULE

A decision of some importance was recently rendered by the State Railroad Commission of Wisconsin. It denied the right of the large water consumers in Milwaukee to a sliding scale of rates. The rate within the city is $9\frac{1}{3}$ cents per 1000 gallons and a number of large consumers appealed against paying this amount. The application was opposed by the City of Milwaukee on the ground that any reduction made to large consumers must necessarily be made up by the large number of small consumers and this would be unfavorable to them. The decision which was favorable to the city established a precedent for waterworks practice, and received unfavorable editorial comment in "Waterworks Engineering." In reply, Mr. Bohmann, Superintendent of Waterworks, Milwaukee, showed that while the rate of $9\frac{1}{3}$ cents was constant, there actually was a sliding scale due to assessments for mains, service pipe and meter based on frontage. A minimum service charge of $2.00 plus $3.25 interest based on 30 feet frontage was imposed which applied to 92 per cent of all consumers, although the use of water ranged from 10,000 to 250,000

gallons. It is evident that, where only 10,000 gallons are used, the rate per 10,000 gallons would be considerably higher to absorb $5.25 than where the same amount is spread over 250,000 gallons. Mr. Bohmann contends that the advantage of a sliding scale is altogether on the side of a comparatively small number of consumers and, where a water utility is municipally owned, there should be no discrimination between consumers.

The difference in distribution cost furnishes a rational reason for the use of the sliding scale and it is rather difficult to justify a sliding scale on any other grounds. Sliding scales where extreme slides of 5 to 1 are still in evidence are legacies of earlier days in waterworks distribution. A sliding scale of 1.5 to 1.0 as applied to small domestic and large manufacturing use can be justified in any average community.

TABLE 6

Statistics on service charges in United States

SIZE OF METER	AMOUNT OF SERVICE CHARGE		
	Highest	Average	Lowest
inches	*dollars*	*dollars*	*dollars*
⅝	8.00	6.13	2.40
¾	14.00	9.96	3.60
1	28.00	18.72	7.20
1½	72.00	42.40	14.40
2	96.00	62.10	24.00
3	232.00	138.00	33.60
4	336.00	205.40	43.20
6	632.00	401.40	72.00

THE AMERICAN AND NEW ENGLAND STANDARD SCHEDULES

In May, 1923, the American Waterworks Association adopted a standard form of rate schedule combining the service charge and sliding scale of three slides with a fourth or special rate for large manufacturers, if deemed desirable. The adopted form is almost identical with the standard of the New England Waterworks Association adopted in 1916. The three slides are for convenience classified as Domestic, Intermediate and Wholesale. While this has the endorsement of the Waterworks Association, it has not had as widespread adoption as the minimum rate.

The service charge for 19 companies or municipalities in the United States which have adopted the Standard Form of Meter Rates is given in table 6.

OTHER FORMS OF RATES

Several other forms have been used to a lesser extent. Many municipalities charge a uniform rate independently of the amount used. The jump scale provides that a certain quantity of water is charged for at a certain price; beyond that limit, while inside another limit, a lower price is named. By this method it is possible to secure a lower bill by drawing an additional quantity of water.

While the number of methods now in use for the collection of water rates appears to be legion, there must be some best method which is applicable to the majority of systems. That there is an utter lack of standardized practice is only too evident. In the electrical field as represented in Ontario by the Hydro Electric Power Commission, we find on all domestic bills a service charge and a minimum charge uniformly in use over the entire system. Some hydro electric officials are inclined to the belief that the present service charge, which is a modification of and an improvement on the former floor area charge, will give way to a straight uniform minimum charge. What is the value of a service charge when a minimum charge prevails at the same time? There cannot possibly be any standardization where rates are based on a "flat" or "complex" system. In a "simple" or "metered" system it should be possible. It is not desirable that all opinions on this subject should be in accord, but it does rest with waterworks officials and executives to install in their own community a rate system which is an equitable measure of the service rendered and which will admit of "value received" being endorsed on every bill.

THE FORT PIERCE FILTER PLANT[1]

By F. P. Larmon[2]

The problem at Fort Pierce was not only the design and construction of a filter plant but finding a suitable supply of water to filter, locating leaks and waste and introducing a new rate that would put the plant on a self-supporting basis.

The old supply was from deep wells which gave a water having a hardness of 330 parts per million and well tainted with salt and sulphur. The available sources of supply were two streams to the north and west which gave a fairly hard water high in color and more or less contaminated and a shallow lake or savannah south of the city, which was a soft but highly colored water. In fact most of the year it has the color of coffee. The savannah, while not ideal as to quantity, is near the city and little subject to contamination. It was decided to use the savannah water and later supplement it with water from one of the streams, if found necessary.

The plant is a standard type of rapid sand filter having two settling basins and three filter beds, each of one million gallons capacity per day and with a covered clear water reservoir of one-half million gallons capacity. The plant is of reinforced concrete including the building over the pumps and filters.

The water is pumped from the savannah by one of three pumps to an aerating device which consists of 12 inch pipes having $\frac{1}{2}$-inch holes drilled in the top so that the water is discharged vertically falling back on itself, flowing around the pipes in a thin sheet and dropping from the bottom into a collecting basin. This aeration drives off the marsh odors and some free CO_2 and raises the pH value from 6 to 6.8. At the outlet from the collecting basin the alum is added, 3 grains per gallon, the water is thoroughly mixed and 1 grain of lime per gallon is introduced. It has been found that, if the lime is added first, it fixes the color so that the alum will not remove it. A floc is formed very rapidly, but on account of the

[1] Presented before the Florida Section meeting, April 12, 1927.

[2] Designing Engineer, Fort Pierce, Fla.

absence of turbidity breaks up easily and settles slowly. The water passes through the settling basins to the filters which are of the standard type with hydraulically controlled valves, operated from tables, one for each filter. From there it goes to the clear well. The discharge into the clear well is arranged so that the water falls in a thin sheet thus giving it a second aerating. The resultant water is absolutely free from color, with a pH value of 7.0 and a hardness of under 70 parts per million.

The water is pumped to the city by one or more of three pumps giving a pressure in town of 70 pounds.

When the work was started here it was found that the office was billing for under 50 per cent of the water pumped. A general checking and cleaning of meters, repairing of leaks in mains and services and installing meters on services that had been lost track of, raised the percentage of "paid for" water to over 75 per cent and increased the revenue $700 in one month, with less pumpage than in the previous month.

Based on a pumpage of one million gallons per day the cost of water as delivered from the new plant will be 9.5 cents per thousand gallons. The cost of distribution, billing, collecting and supervision will be 9.4 cents. These costs include interest and sinking fund.

On the present rates of 10 cents for 1000 gallons the plant showed a deficit of $71 per day so that it was imperative that new rates be established. The new rates were based on the standard form adopted by the American Water Works Association. A service charge was made based on the size of meter installed and a charge for water as follows: First 20 thousand gallons 25 cents, next 40 thousand gallons 20 cents, next 40 thousand gallons 15 cents and all over 100 thousand gallons 10 cents. These rates will put the plant on a paying basis and will eliminate the necessity of carrying the water plant in the general fund.

DISINFECTION OF WATER MAINS[1]

By Charles H. Eastwood[2]

Unquestionably pollution, sometimes of the grossest nature, both avoidable and unavoidable, occurs in new mains, during the process of laying, and even the most uninformed of contractors and operators are sufficiently aware of this fact to carry out flushing of mains before putting them into service.

While this simple flushing is of material benefit, it does not begin to go far enough. Most of us are familiar with the story of the superintendent who, on investigating the inability to close a valve, discovered that its operation was impaired by the presence of an old shoe, presumably thrown into or left in the trench by a laborer, and which subsequently found its way into the main. The mere flushing of mains may serve to remove old shoes, mud and dirt of construction, but it will not do much towards removing bacterial contamination that undoubtedly has been introduced during the time the pipe has been exposed before and during laying.

METHODS OF DISINFECTION OF MAINS

A popular practice is to introduce a small amount of calcium hypochlorite (chloride of lime), roughly an ounce to each joint of pipe, into the pipe as it is laid. When the completed section has been connected up, the section is filled with water and this water is allowed to remain in the pipe overnight. Other than the relative instability of the calcium hypochlorite and the consequent inability to determine the actual presence of available chlorine in anything like constant amounts, there are no objections to this method.

With the almost universal practice of chlorination of water supplies and the availibility of liquid chlorine, water superintendents have more and more shown a desire to use liquid chlorine for sterilization of new mains. Unquestionably it presents the surest means

[1] Presented before the Florida Section meeting, April 12, 1927.

[2] Wallace and Tiernan Company, Newark, N. J.

of achieving the result. Provided some simple, cheap method of introducing it into the main is devised, the operation becomes one of simple routine and is associated with the laying of new mains almost as unconsciously as is the actual digging of the trench.

Almost every superintendent is capable of improvising a connection from the auxiliary tank valve, through a standard corporation cock, into the main. The only problem presenting itself is the extremely corrosive nature of the gas and the need for using connections that will not leak gas, either when first made or later when exposed to the influence of the corrosive effects of the chlorine.

Commercial forms of chlorine control equipment are entirely adapted to the purpose and where duplicate units of the relatively portable type are available at the water works, the problem no longer exists, as it is merely a question of transporting these to the desired point of application.

Where such units are not available a simple piece of equipment may be improvised from a standard connection into a main, such as is used on the smaller types of solution feed chlorine control equipment. This consists of an ordinary quarter inch gate valve fitted with a stuffing box and through which a small silver tube will slide. When desiring to disinfect a newly laid section of main the procedure resolves itself into several simple operations, as follows: The section of pipe should be flushed out thoroughly to remove all dirt, etc. Next tap the main and insert the connection with the silver tube withdrawn and the valve closed. Connect the silver tube through the medium of quarter inch rubber hose directly to the usual auxiliary tank valve on the standard chlorine cylinder. Care should be taken at this point to ensure all connections being gas tight. A little difficulty may be experienced in making the connection at the valve, but, if a valve is retained especially for this purpose, a permanent connection can be made by removing part of the union connection and litharging the joint.

Allow water to enter the section of the main to be disinfected at the minimum possible pressure. Turn on the gas, open the small gate valve and push the silver tube into the main.

It is well to bear in mind that, while we have the pressure of the gas in the cylinder to overcome the pressure in the main, any back pressure due to the pressure of water in the main is reflected back on the gas line and connections. It is advisable to keep this at a minimum.

CHLORINE DOSAGE

Ordinary practice entails a chlorine dosage of from 10 to 20 p.p.m., roughly 80 to 160 pounds of chlorine per million gallons of water.

This means that the water should be allowed to flow freely from the end of the section being sterilized until such time as it shows a heavy orange red color to the ortho-tolidine test, at this end of the pipe.

The silver tube can be withdrawn, the valve closed and the gas cut off. The closing of the valve and the cutting off of the gas should be done as nearly simultaneously as possible to avoid the building up of excessive gas pressure in the hose line or allowing water to get back to the cylinder valve. The valve is removed and the hole is plugged.

The heavily chlorinated water should be allowed to stand in the main for several hours and the main subsequently thoroughly flushed with fresh water to remove all excess chlorine.

Innumerable improvements in equipment and technique, ranging all the way from the simple addition of a standard diffusor and check valve to the use of standard solution feed equipment, present themselves to those familiar with chlorine gas control and chlorine gas control apparatus. Personally I should much prefer to amplify the method outlined through the use of a standard direct gas feed diffusor and chlorine check valve with the connections made through copper pipe and the usual union connection properly packed with gaskets. This means a larger investment, however, and would only be justified where there is considerable new main to be laid.

No accurate control of the chlorine dosage is possible or necessary with this method. The object is to put in chlorine and lots of it. As the cost of the gas is relatively small and the excess chlorine is subsequently removed by flushing the main, anything other than rough ortho-tolidine control is superfluous.

THE WHITE RIVER SURVEY[1]

By W. F. King[2]

The survey of White River was undertaken for the purpose of determining the degree and extent of pollution of the stream by domestic sewage and industrial waste from a number of cities located on the river and its tributaries. White River is an important stream, since it provides the only possible sewage outlet for an urban industrial population of more than one-half million, and at the same time furnishes a considerable part of the water supply for the same population. As the years go by, it is plain that not only will the population and industrial development of these cities increase, but that White River and its watershed must furnish more and more of the water supply for this population. In any effort to conserve and safeguard this water supply, the facts as determined in this survey should be helpful.

PLAN OF SURVEY

At a meeting attended by representatives of the State Conservation Department, the Sanitary District of Indianapolis, the Indianapolis Water Company, Indianapolis Health Department and the State Board of Health, a plan was agreed upon for conducting the survey. The Indianapolis Water Company collected samples for bacteriological and chemical examinations from a point above any sewer outlets at Muncie to the filter plant intake at Indianapolis. The Indianapolis Sanitary District collected samples from Washington Street, Indianapolis, to Martinsville, while the State Board of Health collected samples from Martinsville to Spencer. A total of twenty-eight sampling points was chosen extending along the river for a distance of approximately one hundred and fifty miles.

Samples were collected weekly, except during a few months of the winter of the years 1925 and 1926, when samples were collected once each two weeks. The actual field work was begun in July, 1925, and sampling was continued until October 1, 1926.

[1]Presented before the Indiana Section meeting, February 17, 1927.

[2]Secretary, State Board of Health, Indianapolis, Ind.

Coincident with the collection of samples the State Conservation Department, the Indianapolis Water Company and the Indianapolis Sanitary District began gauging White River and Fall Creek.

In the examination of samples the following determinations were included:

1. Alkalinity
2. Turbidity
3. Temperature
4. Dissolved oxygen
5. 5-day bio-chemical oxygen demand
6. Bacterial count—20°C.
7. Bacterial count—37°C.
8. B. coli content

In addition to the collection of samples and gauging, field surveys have been made and are being made to determine the sources of pollution along this part of the course of White River. Mr. Berg of the Conservation Department covered this part of the river five times at intervals of approximately three months, to determine the physical condition of the river and the extent of "larger biologic life" in the stream. Mr. Diggs of the State Conservation Department has made a survey of the larger industrial plants along the river to determine the amount and the physical characteristics of their industrial wastes. The State Board of Health is at present engaged in making a survey of the cities along the river for the purpose of determining the amount of domestic sewage which is being discharged into the stream. The city engineers and water works officials of the various cities along the stream have coöperated in the survey and have rendered valuable aid. The duty of coordinating the various parts of the survey into a completed report is being carried by the State Board of Health.

PRELIMINARY FINDINGS

While it is impossible to give a complete report of the survey at this time and to state any definite determinations or conclusions based upon the information obtained in the survey, some general observations may be made. The summer of 1925 after the survey was started was very dry and extremely low river stages occurred. The flow in the river at Anderson averaged 196 second feet during July, August and September 1925, while, during the same months in 1926, the flow was 1108 second feet. These two flows correspond

to 1470 and 8310 gallons per second at this point. The maximum average flow during any month of the entire survey occurred in September, 1926, when the average flow was 2587 second feet. The minimum average monthly flow occurred in August, 1925, with 41 second feet.

In the river above Indianapolis, the two points of maximum bacterial load were at Yorktown and Moss Island, i.e., below Muncie and Anderson. The data for the stretch below Indianapolis have not yet been compiled.

During the summer of 1925, the river at Moss Island was several times found to be devoid of dissolved oxygen. As would be expected, considering the low flow, the river was in its worst condition during July, August, September, 1925.

Mr. Berg, in his survey, reported the river in a foul condition at several points, i.e., a noticeably foul odor arose from it and no signs of fish life were noted.

Since the Indianapolis sewage disposal plant has been in operation the condition of the river below Indianapolis has improved to the extent that fish are now being caught at points where the river formerly would not support such life.

One type of industrial waste which caused trouble from 1903 until a few years ago has ceased to be a problem, i.e., the pollution of the river by oil well wastes. The petroleum wells produced oil and salt water, the salt water being drawn off and allowed to discharge into the nearest stream. This, with floating oil, caused a nuisance.

SOURCES OF WATER SUPPLY AND NATURE OF SEWAGE DISPOSAL

Of the towns and cities along the river the following use well supplies exclusively: Noblesville, Yorktown, Martinsville, Gosport and Spencer. Indianapolis, Anderson and Muncie draw their supplies from the river and also from wells.

At Muncie, Anderson, Noblesville, Martinsville and Spencer raw sewage, both domestic and industrial, is discharged into the river, Indianapolis being the only city to treat sewage.

Typhoid fever data from the various cities have not been compiled, but they will be and will furnish interesting facts.

Muncie, at present, is having a survey made to determine the proper method of collecting and treating its sewage, although they have not yet committed themselves to any actual construction work.

Anderson has been considering having a survey made, but, as far as is known, has not yet definitely decided to make the study.

In general, it may be stated that there is an excess of pollution in White River under any ordinary condition of stream flow below the city of Muncie, reaching its peak at or near Yorktown, with a similar condition below the city of Anderson, reaching its peak at or near Moss Island, with a slight excess of pollution shown below the city of Indianapolis, reaching its peak at or near Antrim. This excess pollution is particularly noticeable during the normal dry weather flow of the stream below Muncie and below Anderson. The excess pollution below the city of Indianapolis will undoubtedly disappear when the Indianapolis sewage treatment plant is in full operation and when all the sewage and industrial wastes of that city are subjected to treatment.

COMMENT ON A RECENT REPORT[1] ON "STANDARD METHODS OF WATER ANALYSIS"

By Emery J. Theriault[2]

In view of the widespread adoption of "Standard Methods for the Examination of Water and Sewage" and of the importance, in general, of accurate and workable methods of sanitary analysis, it has appeared advisable to the writer to present at this time the following comment on the "Report of Committee No. 1 on Standard Methods of Water Analysis" recently published in The Journal. The discussion will be limited to those sections of the report which refer to the determinations of (1) dissolved oxygen, (2) free chlorine, (3) biochemical oxygen demand, and (4) phenols in water supplies. On the whole, such criticism as may be offered will be based on experimental evidence which was not available to the various referees at the time (Buffalo Convention, June 11, 1926) when the report in question was submitted for publication.

I. THE DETERMINATION OF DISSOLVED OXYGEN

In the discussion which followed the original presentation of the permanganate modification of the Winkler method for dissolved oxygen, Rideal and Stewart (1901) stated that "Even in the presence of nitrites, ferrous iron and a large quantity of organic matter, this process gave results almost identical with the gasometric figures." The permanganate process recommended by Rideal and Stewart was first included in "Standard Methods" in 1917 and, in the sixth or 1925 edition of "Standard Methods" it is specified that this modification be used for the determination of the dissolved oxygen content of "polluted streams and other waters containing 0.1 part per million or more of nitrite nitrogen."

As regards the effectiveness of the Rideal-Stewart modification

[1] Report of Committee No. 1 on Standard Methods of Water Analysis, Jack J. Hinman, Chairman. Presented before the Buffalo Convention, June 11, 1926. Published in the January, 1927, issue of The Journal, pp. 112–126.

[2] Chemist, U. S. Public Health Service, Cincinnati, Ohio.

in counteracting the effect of nitrites, it is generally agreed that the method leaves little to be desired, at least if the full 20-minute period of action is allowed. However, as evidenced by data presented in Public Health Bulletin No. 151 (Theriault, 1925), it is necessary to conclude that as a corrective for "organic matter" the permanganate treatment has been overrated. Moreover, on the basis of the fairly conclusive evidence presented in the same Bulletin, it would appear that, in the presence of iron salts, the procedure outlined in "Standard Methods" should be perhaps modified to meet conditions which will presently be discussed.

The possibility of interference by iron salts was mentioned by Winkler (1888) and was further emphasized by Winkler (1915) who proposed the use of phosphoric acid for the final acidification when large amounts of iron were present. For small amounts of iron the use of sulfuric acid (instead of hydrochloric acid) was apparently considered a sufficient precaution. Winkler's results were fully confirmed by Bruhns (1916). Hydrochloric acid was found to aggravate the difficulty. The results presented by Bruhns indicate that iron up to 100 parts per million or over does not offer any serious difficulty.

In this country, Swanson and Hulett (1915) first called attention to the fact that "in attempting to determine the dissolved oxygen in mine waters, the presence of both ferrous and ferric iron interferes with the usual procedure." Buswell and Gallaher (1923) have also reported on the interference of iron salts "in attempting to determine the dissolved oxygen in a stream polluted with waste liquor from a galvanizing plant as well as domestic sewage." Without knowledge of the earlier work of Winkler (1915) and of the fairly extensive report by Bruhns (1916), these experimenters conclude that "Since the Winkler method apparently could not be modified for use in the presence of iron, the next step was to investigate some other method. Of those mentioned (above) the Levy-Mohr method seemed to be the one most likely to work in the presence of iron, since an iron solution is added during the procedure and therefore any iron already in the water should have no effect."

In passing, it should be noted that the tests cited by Buswell and Gallaher in support of their conclusions were performed on solutions which contained only potassium iodide, ferric salts and hydrochloric acid, so that the conditions of their experiments conformed more nearly to those recommended for the determination of iodides by ferric

chloride than to those prescribed in the Rideal-Stewart modification of the Winkler method. Moreover, the titrations were delayed for 12 hours.

A repetition by the writer (Theriault, 1925) of the experiments of Buswell and Gallaher led to certain conclusions which may briefly be summarized as follows:

a. Low results will, of course, be obtained when the unmodified or original Winkler method is applied to samples containing ferrous salts. The error is in the neighborhood of 0.14 part per million of dissolved oxygen for each part per million of ferrous iron. With most waters, therefore, the error is negligibly small.

b. In the absence of other interfering substances, accurate results may be obtained when the Rideal-Stewart modification of the Winkler method outlined in "Standard Methods" (1925, p. 60) is applied to samples containing relatively large quantities of either ferrous or ferric salts, provided that the decolorization of the samples by oxalates (following the addition of permanganate) is accomplished in the dark and that the titrations are performed immediately after the final acidification.

c. The necessity for conducting the decolorization in the dark arises from the fact that, under the experimental conditions, the reduction of ferric salts is greatly accelerated by sunlight. When this precaution is neglected the results will appear too low. On the other hand, should the decolorization be imperfect, the results will appear unduly high.

d. "Under the particular conditions imposed by the Rideal-Stewart modification, the decolorization of the permanganate by oxalates is retarded to a surprising extent when iron salts are present. Fluorides (2 cc. of a 40 per cent solution of $KF \cdot 2H_2O$ in 300 cc. of sample) may be used to good advantage to diminish the period of decolorization and to eliminate interference due to iron salts when the delay before titration does not exceed one hour."

e. "Phosphoric acid ('4 cc. of 85 per cent H_3PO in 300 cc. of sample') should be substituted for sulfuric acid (for the final acidification) when the delay before titration is protracted."

Primarily, therefore, the use of potassium fluoride has been suggested by the writer as a means of inducing a more rapid decolorization of the samples. Apart from this beneficial effect, potassium fluoride in the amounts stated is also fairly effective in repressing the deleterious effect of iron salts. Owing to its limited solubility, the

use of the less expensive sodium fluoride is restricted to samples which contain relatively small amounts of iron (cf. Public Health Bulletin No. 151, pp. 35 and 36). In laboratories where the titrations must of necessity be delayed, the modified Winkler procedure should be used (Winkler, 1915; Bruhns, 1916). Essentially, this modification consists in the substitution of phosphoric acid for sulfuric acid in the final acidification.

It is difficult to reconcile the foregoing statement of the recommendations actually made in Public Health Bulletin No. 151 with the following abstract given on page 120 of the January issue of THE JOURNAL:

> In Public Health Bulletin No. 151 ("The Determination of Dissolved Oxygen by the Winkler Method") it is suggested by the author, E. J. Theriault, that the oxidizing effect of ferric chloride could be inhibited by the addition of sodium fluoride, and he proposed this as a modification of the Winkler method for liquors containing iron. Unfortunately, he did not use in his experiments as large amounts of iron as are sometimes found in actual field tests, and until further work is done along this line, the advisability of including his suggested modification is still somewhat in doubt.

It is earnestly recommended that, when further work along these lines is undertaken by the Committee, due consideration be given to the combined use of potassium fluoride and phosphoric acid, following the procedure set forth in detail in Public Health Bulletin No. 151.

As indicated by the data presented in that Bulletin, the procedure actually recommended is apparently capable of giving exceedingly accurate results in the presence of 120 parts per million of iron even when the titrations are delayed for 8 days. At the time when these experiments were made, it was believed that this degree of flexibility would satisfy the conditions usually encountered in sanitary chemical work. The method is no doubt capable of giving accurate results even when the figure of 120 parts per million of iron is greatly exceeded. Likewise, the figure of 8 days refers to the duration of a particular experiment and not to an upper limit of applicability. As a practical matter, it is to be borne in mind that the dissolved oxygen in a waste may be of negligible importance when its ferrous iron content greatly exceeds 100 parts per million.

II. THE DETERMINATION OF FREE CHLORINE

In connection with the studies reported by Buswell and Boruff on the preparation of the orthotolidine reagent for use in the deter-

mination of free chlorine, attention is directed to a brief article by Roake (1925). Roake found it difficult to prepare an orthotolidine solution in accordance with the directions given in "Standard Methods" (Sixth Edition, p. 44). The orthotolidine does not dissolve completely, at least in a reasonable time, and, on filtering off the undissolved part, a weaker solution is obtained than called for. He gives the following directions for preparing the reagent:

> To 1 gram of *o*-tolidine add the calculated amount of hydrochloric acid ("about 236 cc."), stir well, dilute to about 500 cc. and filter. The residue left on the filter will be found to be soluble in distilled water. Make up to 1 liter.

The following procedure avoids the filtration recommended by Roake and has been found very satisfactory both in this and in several other laboratories·

a. Transfer one gram of orthotolidine to a 6-inch mortar, and add 5 cc. of 1:5 hydrochloric acid (previously prepared by adding 100 cc. of concentrated hydrochloric acid, specific gravity 1.18–1.19, to 400 cc. of distilled water).

b. Grind to a thin paste and add 150 to 200 cc. of distilled water. The orthotolidine goes into solution immediately.

c. Transfer to a 1000 cc. graduate and make up to 505 cc. with distilled water.

d. Make up to the 1000 cc. mark by adding the balance (495 cc.) of the 1:5 hydrochloric acid.

The reader is referred to Public Health Reports, March 11, 1927, for further details.

III. THE DETERMINATION OF BIOCHEMICAL OXYGEN DEMAND

With reference to the so-called "second stage" of deoxygenation, the Committee on Standard Methods presents the following comment:

> Results have shown that the demand for oxygen is far from being satisfied in twenty days at 20°C., but that absorption takes place in two stages, the first extending over ten days at 20°C., the second over a period of months. In explanation of the secondary phase, Theriault believes that it is the stage of nitrification, while the first stage is the stage of carbon oxidation; Greenfield and Elder believe the secondary phase is primarily the demand of dead organisms. The latter investigators claim the second stage was not obtained with sewage, but only with river water, while Theriault claims to have had similar results both with sewage and river water. This divergence of opinion must be reconciled by further work.

In this connection attention is invited to a more recent publication by Greenfield, Elder and McMurray (1926), in which the conclusion is reached that the presence or absence of either living or dead plankton "does not explain the second period of acceleration in deoxygenation curves. . . . ."

> It was suggested by Theriault that these two-stage curves were best explained by the work of Adeney in which he showed that in the oxidation of organic matter the first stage was one of carbonaceous oxidation, which was followed by a stage of nitrification of nitrogenous compounds. . . . . The results seem to be a confirmation of Adeney's theory of two-stage oxidation.

In their experiments, however, both Greenfield and Elder (1925) and, more recently, Greenfield, Elder and McMurray (1926), appear to have assumed that sewage is free from plankton. A systematic error is thereby introduced in their work which seriously vitiates their conclusions. Unpublished data obtained in the Stream Pollution Laboratory of the United States Public Health Service would indicate that the plankton are undoubtedly active in promoting deoxygenation.

IV. THE DETERMINATION OF PHENOLS IN WATER SUPPLIES

Attention is invited to the comprehensive review of tests for phenols which has recently been prepared at the Hygienic Laboratory of the United States Public Health Service (Gibbs, 1926).

REFERENCES

Bruhns, G. 1916. The determination of iron by the Winkler method. Chem. Zeit., **40**: 45–6.

Buswell, A. M., and Gallaher, W. U. 1923. Determination of dissolved oxygen in the presence of iron salts. Ind. Eng. Chem., **15**: 1186–8.

Gibbs, H. D. 1926. Phenol Tests. 1. A classification of the tests and a review of the literature. Chem. Reviews, **3**: 291–319.

Greenfield, R. E., and Elder, A. L. 1926. The effect of temperature on the rate of deoxygenation of diluted sewage. Ind. Eng. Chem., **18**: 291–4.

Greenfield, R. E., Elder, A. L., and McMurray, R. E. 1926. Further studies on the biochemical oxygen demand test. Ind. Eng. Chem., **18**: 1276–9.

Roake, C. E. 1925. Preparation of *o*-tolidine solution for estimation of chlorine. Ind. Eng. Chem., **17**: 257.

Swanson, A. A., and Hulett, G. A. 1915. The determination of gases dissolved in waters and effluents. Jour. Amer. Chem. Soc., **37**: 2491.

THERIAULT, E. J. 1925. The determination of dissolved oxygen by the Winkler method. Public Health Bulletin No. 151, pp. 1–43.

THERIAULT, E. J. 1925. The rate of deoxygenation of polluted waters. Proc. Am. Soc. Civil Eng., **51**: 1819–28. Reprinted in Public Health Reports, **41**: 207–17 (1926).

THERIAULT, E. J. 1927. The orthotolidine reagent for free chlorine in water. Public Health Reports, **42**: 668–72; Reprint No. 1145.

WINKLER, L. W. 1888. The determination of oxygen dissolved in water. Ber., **21**: 2843–54b.

WINKLER, L. W. 1915. The determination of dissolved oxygen in polluted waters. Z. Nahr. Genussm., **29**: 121–8.

DISCUSSION

A. M. BUSWELL:[3] Captain Theriault states that the criticism of the Winkler Method by Buswell and Gallaher is based on experiments which "conformed more nearly to those recommended for the determination of iodides by ferric chloride than to those prescribed in the Rideal-Stewart modification of the Winkler Method. Moreover, the titrations were delayed for twelve hours." We wish to call attention to the fact that the criticism of the Winkler Method was based on field experience with the method carried out with the Rideal-Stewart modification as specified by Standard Methods. In this field work titration results showed considerable quantities of dissolved oxygen, although the conditions were such that the sample contained no dissolved oxygen. The experiments to which Theriault refers, as the article clearly indicates, were carried out to determine whether under the most favorable conditions the reaction with iron was sufficiently complete to warrant making a correction of the figure obtained by the Winkler Method (Rideal-Stewart Modification), if the iron content were known. Since this was not found practicable under conditions which favored the reaction between iron and salts, further attempt to determine a correction factor was abandoned. The intent of the article is stated by Buswell and Gallaher as follows:

> Whether or not the criticisms of this method are false cannot be judged without a much fuller investigation. The data, however, show that the Levy method can be used in the presence of iron and will give far more accuracy than the Winkler Method, Rideal and Stewart modification.

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[3] Chief, State Water Survey Division, Urbana, Ill.

Concerning the determination of biochemical oxygen demand Mr. Elder has furnished the following statement:

Since Greenfield, Elder, and McMurray were working with quite high concentrations of plankton in the river water[4] dilutions, relatively, therefore, the number of plankton in sewage was negligible. It was never assumed by them that sewage was free from plankton.

Attention is called to the work of Greenfield, Elder and McMurray on the effect of salt concentration on[4] biochemical oxygen demand. By adding certain inorganic salts to the double distilled dilution water, two-stage biochemical oxygen demand curves were obtained. Nitrification was also noted under these conditions.

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[4] See Theriault bibliography, loc. cit.

ELECTROLYTIC CHLORINATION

C. T. HENDERSON:[1] Harry N. Jenks' excellent paper entitled "Electrolytic Chlorination at Sacramento Filtration Plant"[2] is particularly interesting to the writer on account of his experience over a number of years in the design, construction and operation of electrolytic plants of the same general character, but of much greater magnitude.

Mr. Jenks is certainly to be congratulated on the thoroughness with which he has covered the present situation. The City of Sacramento is certainly fortunate in having a man of Mr. Lundelius' qualifications available, for he is able not only to design, but to operate electrolytic cells. The availability of Mr. Lundelius has made possible the construction of electrolytic cells at Sacramento without engineering or license fees, but for future installations it would seem only proper to increase the capital charge and include engineering fees for design, and license fees for use of patents covering the type of cells installed. The cells described by Mr. Jenks seem to infringe several patents and yet there is no item of royalty or license included in the itemized statement of plant costs.

The cost figures given by Mr. Jenks show no operating labor costs, presumably on the theory that no extra labor is involved over that required to run the filter plant. This seems an obvious fallacy for by following this line of reasoning to its logical conclusion, nothing in the plant would cost anything, since, after all, each individual operation carried on may be said to be carried on in spare time. Certainly, however, there is extra labor involved, for example, in the handling of the 191 tons of salt required by the plant in the course of the year. This handling at 50 cents per ton would amount to 0.11 cent per pound of chlorine produced. It would, also, seem only fair to charge say $150 per month for supervision, laboratory checks, etc., which at 100 per cent scale of operations will amount to 2.16 cents per pound of chlorine produced.

[1] Vice-President, Great Western Electro-Chemical Company, San Francisco, Cal.

[2] See JOURNAL, May, 1927, page 514.

Mr. Jenks figures no repairs on brine equipment. Those familiar with the corrosive effect of saturated brine will agree that no doubt repairs will be required on the brine equipment at frequent intervals.

Again, Mr. Jenks' figures on depreciation for electrical machinery seem too low. Does the reader know of a half dozen pieces of electrical equipment twenty years old which are in regular service today? Yet Mr. Jenks assumes in his cost estimates a twenty-five-year life for his electrical equipment; a fifteen-year life seems more nearly correct to the writer. Also, accidents are bound to occur to electrical machinery, yet no electrical repair charges are included in the cost figures.

In calculating cell maintenance Mr. Jenks apparently makes the assumption that the labor cost of completely rebuilding the cell will be the same as the original labor cost of construction. The writer's experience shows that repair labor will be at least 50 per cent greater than the original labor required to construct.

Again, figures for the life of the various parts of the electrolytic cells do not agree with the writer's experience and observations. The principal differences are in the life of anodes and effluent pans. The writer's experience in this connection would indicate that anode life will be approximately nine months and the life of effluent pans two years, as against two and five years respectively, taken in Mr. Jenks' estimate. Also, diaphragm renewals will cost, according to the writer's experience with cells of similar size $4.77 each.

Correcting for the above differences, we have the revisions of tables 2 and 3.

Tables 4 and 5 have likewise been revised in accordance with revised tables 2 and 3, and have been extended to show the effect of operating at 80 and 90 per cent of *full* capacity, since variations in chlorine dosage will preclude possibility of full operation at all times.

In making up table 5, the price of liquid chlorine has been taken as 8.25 cents per pound, since liquid chlorine in one ton containers is available at Sacramento, California, at the price of $8\frac{1}{4}$ cents per pound.

An analysis of the foregoing figures shows that even on the basis of 100 per cent operation, the electrolytic plant produces chlorine at a higher cost than purchased chlorine, while at lower productions the cost of "home made" chlorine materially exceeds that of purchased chlorine.

It is indeed regrettable that after two and one-half years actual

REVISED TABLE 2

Schedule of chlorine plant depreciation

	PROBABLE USEFUL LIFE	STRAIGHT LINE ANNUAL DEPRECIATION
	years	*per cent*
1. Brine equipment	10	10
2. Electrical equipment	15	6.66
3. Chlorine lines	5	20
4. Electrolytic cells		
a. Cell body	5	20
b. Cell cover	1	100
c. Anode assembly	$\frac{3}{4}$	133
d. Cathode plate	1	100
e. Effluent pan	2	50
f. Diaphragm	$\frac{1}{4}$	400
g. Electrical connections	2	50

REVISED TABLE 3

Annual fixed charges, electrolytic chlorine plant Sacramento, California

	COST	ANNUAL STRAIGAT LINE DEPRECIATION	
		Per cent	Total
1. Brine equipment	$1,500	10	$150.00
2. Electrical equipment	4,800	6.66	319.68
3. Chlorine lines	275	20	55.00
4. Electrolytic cells	1,596	Various	1,292.33
	$8,171	11.7	$1,816.91
Assume interest charges at 5 per cent (0.05 × $8,171)			$408.55
Total annual fixed charges			$2,225.46
Capital cost of chlorine on basis of *full* plant production, per pound of chlorine			$0.0267
Capital cost of chlorine on basis of 90 per cent plant production, per pound of chlorine			0.0297
Capital cost of chlorine on basis of 80 per cent plant production, per pound of chlorine			0.0334

operation of the Sacramento plant there are no definite *actual* cost figures available and that the merits of the installation must be considered on the basis of *estimated* costs which are always contro-

versial. The experienced operator of chlorine plants who has been compelled to show profits to a doubting board of directors is apt to be conservative and estimate higher than the man whose experience has been limited and who does not realize the high maintenance costs, after three or four years, which are inevitable in a chlorine plant. It takes time for the corrosion to start making trouble with

REVISED TABLE 4

Summary of actual cost of manufacture of electrolytic chlorine at Sacramento Filtration Plant

	PER POUND OF CHLORINE		
	80 per cent	90 per cent	100 per cent
	cents	*cents*	*cents*
Capital charges	3.34	2.97	2.67
Operating cost:			
Electric current 2.30			
Salt 1.72	4.02	4.02	4.02
Salt handling	0.11	0.11	0.11
Supervision @ $150.00 per month	2.70	2.40	2.16
	10.17	9.50	8.96

REVISED TABLE 5

Analysis of cost of chlorination with liquid chlorine in comparison with that of electrolytic chlorination

	COST PER POUND OF CHLORINE		
	80 per cent	90 per cent	100 per cent
	cents	*cents*	*cents*
Liquid chlorine apparatus annual fixed charges	0.79	0.70	0.63
Liquid chlorine, operating cost	8.25	8.25	8.25
Total	9.04	8.95	8.88

certain major parts of the equipment, but after the trouble starts it is seemingly unending.

The writer's conclusions in the matter would be that in no case would it pay a municipality to consider the production of their own chlorine unless a man of Mr. Lundelius' experience and capabilities is available, and that, even with such a man available, the cost of

"home made" chlorine will at least equal, and if *proper labor charges are actually applied to the production of chlorine*, exceed the cost of purchased chlorine.

HARRY N. JENKS:[3] In discussing such a subject as the one presented in the writer's paper on electrolytic chlorination, it appears only natural that there should be considerable room for differences of opinion on the very points emphasized by Mr. C. T. Henderson. In the interests of a clear understanding of the situation, however, one should bear in mind that the matter is viewed by Mr. Henderson largely from the manufacturer's standpoint, while the purpose of the writer's paper was primarily to call attention to the fact that electrolytic chlorination may be a profitable undertaking as an adjunct to water treatment, as proved by ample experience at Sacramento.

The writer is not disposed to take issue with Mr. Henderson on questions concerning the manufacture of chlorine as such, for it will be recognized that his contentions relating to labor and certain depreciation charges would be entirely pertinent in the case of a liquid chlorine plant. In the interests of strict accounting, it may be admitted that the item of supervision should be included as a separate charge. It will be apparent to water works operators, however, that the operation of an electrolytic chlorine plant is in no essential different from that of a liquid chlorine installation, and constitutes one of the regular duties of the filter operators. The writer believes that the operating cost for the two methods in general would be about the same, and in the comparison between them on the basis of cost, no extra charge should be made against either.

In any event, sufficient allowance in cost figures has been made to cover handling of salt, since salt may be obtained f.o.b. the filtration plant for $7.10 per ton, whereas $7.50 per ton has been allowed. Moreover, the writer cannot agree that $150 per month is a correct figure to use for laboratory tests and supervision of the plant. As every water works operator knows, in medium and large sized plants such checks are quite incidental to the volume of routine analyses performed, and at the most would not amount to half Mr. Henderson's proposed charge. Again, the writer would point out that this same charge should be made against any standard chlorine equipment when cost comparisons are to be made.

[3] Sanitary Engineer; Associate Professor of Sanitary Engineering, Iowa State College, Ames, Iowa.

Mr. Henderson criticizes the lack of maintenance charges against the brine equipment. As a matter of fact such a charge has actually been allowed for under the heading of depreciation. During two and one-half years' operation, no repairs of any kind have had to be made amounting to more than $5 or $10. A similar observation applies to the electrical equipment. Especially with duplicate motor-generator apparatus, there is no good reason to suppose that it should not give satisfactory service for twenty-five years. Even a General Electric representative might admit as much relative to Westinghouse equipment!

As to the labor cost of rebuilding a cell, it is anticipated that the expense, rather than being 50 per cent greater than for the original equipment, may in reality be somewhat less, because of the patterns and plans already at hand to serve as a guide.

In reference to Mr. Henderson's experience and observations on the life of anodes and effluent pans, there can be little doubt but that with a less rugged and straightforward design for these parts, a life of only nine months and two years, respectively, may be expected. With the cells as designed at Sacramento, the writer's experience has been different from Mr. Henderson's, although not necessarily untrustworthy on that account. Mention of the design of the cells reminds the writer to state that, because they embody several novel and improved features, they are themselves patentable and presumably do not infringe on similar patent rights. However, the design of the Sacramento cells is not patented and may be freely followed by those who wish to make their own equipment.

Regarding Mr. Henderson's statement that "it is indeed regrettable that after two and one-half years actual operation of the Sacramento plant, there are not definite *actual* cost figures available," the writer is tempted to ask what costs other than actual costs can actual operation disclose?

Again, in answer to Mr. Henderson's last paragraph, the writer, with all due respect to Mr. Lundelius' experience and ability, may be pardoned for expressing his modest belief that in every water filtration plant of note in this country there is enough executive and technical skill available for the purpose of designing and operating a small electrolytic chlorine plant along with the multitude of more intricate problems daily met and solved by water works superintendents.

Finally, and what is more to the point than argumentation, the writer has learned from engineering friends in California that the operation of the Sacramento electrolytic chlorine plant has already led to a substantial lowering of the price of liquid chlorine on the Pacific Coast. Accordingly, in closing, the writer wishes to correct one of the conclusions of his paper, to the effect that "the advantage of electrolytic chlorination is dependent primarily on there being a substantial margin between the market price of liquid chlorine and the actual cost of production locally at the treatment plant, a condition that prevails in the West." This should now read, "a condition that *used* to prevail in the West," if the writer's information on this point is correct. Hence it appears that Mr. Henderson in the end has proved at least this part of his thesis, that "in no case would it pay a municipality to consider the production of their own chlorine," provided it is remembered that electrolytic chlorination costs have not gone up, but that, instead, liquid chlorine prices have come down.

John Ericson

Died April 16, 1927

In the sudden death of John Ericson, City Engineer of Chicago, the water works profession has lost an eminent engineer and this society an honored and respected member. News of his passing was a great shock to all. His death was particularly untimely in view of the active part he was taking in preparing for the 47th Annual Convention of the American Water Works Association. It was under his direction, as chairman of the Chicago local committee, that most elaborate plans had been made for the greatest water works meeting in the history of the association. He was scheduled to read at the "Chicago Night" session on Tuesday, June 7, a paper entitled "A Program for Improving the Water Service in Chicago," and considering the thoroughness with which he prepared material of this kind this paper would probably have been a classic contribution toward the solution of Chicago's water supply problems.

John Ericson was born October 21, 1857, in Stockholm, Sweden. He was graduated from the Royal Polytechnic Institute in that city in 1880, receiving the degree of Civil Engineer. After being employed on bridge construction work in Sweden for a year he came to the United States. He began his engineering career in America as a rodman for the Pennsylvania Railroad and was promoted to a resident engineer by that company in 1882. In 1883 he was engaged in survey work on the Illinois-Michigan Canal.

Mr. Ericson began his career in the employ of the City of Chicago in 1884 as a draftsman, which position he held for two years. In 1886 he accepted a position as assistant engineer with the city of Seattle, in connection with the design of the new water works for that city. In 1890 he returned to Chicago and was employed for two years as an assistant engineer with the Sanitary District. He re-entered the employ of the City of Chicago in 1892 as an assistant

engineer on water tunnel construction work, where he rendered exceptional service. In recognition of his work Mr. Ericson was made first assistant city engineer in 1893. On July 6, 1897, he was appointed to the position of City Engineer. He served continuously in this office until his death, except for a four-year period, 1919 to 1923, when he was employed as consulting engineer to the Department of Public Works.

When Mr. Ericson first entered the employ of the City in 1884 the Chicago water works system consisted of one crib, 11 miles of tunnels, 2 pumping stations having a capacity of 134 M.G.D. and about 533 miles of cast iron pipe in the distribution system. At the time of his death this system had increased to 6 intake cribs, 70 miles of tunnels, 11 pumping stations and 3400 miles of cast iron mains.

During the 43 years of his service Chicago had a phenomenal growth as a city. The engineering problems in developing the water works system to meet the demands for an increased supply required engineering skill and foresight of a high order. Through the period of multiple annexations of suburbs, each with its own water supply system, there was serious need for the formulation of a sound technical program for the building of a great water works system from these many units. It was indeed fortunate for Chicago that it had at the head of its Engineering Bureau a man of Mr. Ericson's high qualifications. He may truly be called the builder of the present water works system in Chicago.

As City Engineer Mr. Ericson had charge of the design and construction of many bridges for the City of Chicago during the last three decades. He designed a type of bascule bridge in 1898 that enabled the city to build its bridges without paying royalties. In 1909 he submitted an excellent report on investigations of underground conditions affecting the future subway construction. From 1911 to 1914 he served on the Harbor and Subway Commission. Projects under construction now which were designed and begun under his direction are the Western avenue pumping station and the new Chicago avenue tunnel.

For years Mr. Ericson advocated filtration of Chicago's water supply and in 1925 submitted to Colonel A. A. Sprague, Commissioner of Public Works, an official report on "The Quality Problem in Relation to Chicago's Water Supply," in which specific recommendations were made for the construction of an experimental filter plant to be operated over a period of years to enable the collection

of fundamental data on which to base the design of filtration plants for the city. This experimental plant is now under construction.

Mr. Ericson was an active member in the American Water Works Association and contributed many valuable technical papers to its programs. Last year in Buffalo his paper on "Universal Metering In Chicago" was enthusiastically received, being typical of the engineer he was in its thoroughness. He was a member of the American Society of Civil Engineers, the Western Society of Engineers, the American Society of Mechanical Engineers, the American Association of Engineers, the Swedish Engineers Club and the Swedish Club. He was a Mason, Shriner and Knights Templar.

In 1912 Mr. Ericson was awarded the Octave Chanute medal of the Western Society of Engineers for a paper reporting the results of extensive experiments to determine the flow of water in the northwest land tunnel. Mr. Ericson was decorated with the Royal Order of Vassa by the King of Sweden in 1913.

Mr. Ericson is survived by his wife, Esther Malmgren Ericson, and a daughter, Mrs. Ralph Haven Quinlan of California.

ARTHUR E. GORMAN.

Fred C. Smith

Died November 16, 1926

Fred C. Smith, superintendent of the water department, Euclid, Ohio, died suddenly on November 16, 1926.

Mr. Smith is survived by his wife and five sons. The family has lived in this vicinity about 11 years, moving from Ashtabula, where Mr. and Mrs. Smith were married. He was born in Rootstown, Portage county, 50 years ago, July 3 last.

Mr. Smith was elected a member of the board of public affairs of Euclid village in November, 1925. He resigned soon after taking office in January, however, and was appointed water superintendent by the other two members of the board.

Mr. Smith followed the plumber's trade for 24 years. He had been in business for himself at his home about a year before taking charge of the Euclid department. Previous to that he had been employed by the Wehrle Hardware Company of East Cleveland. Mr. Smith is credited with having invented the modern drinking fountain for school and public building use.

Oscar E. Bulkeley

Died January 4, 1927

Oscar E. Bulkeley was born April 2, 1885, at Oneida, Ill. His parents were John A. and Emma H. Bulkeley. With his parents, at the age of five years, he moved to Grand Junction, Col. There his mother died when he was 12. Three years later he and his father went to Riverside, Cal., where his high school education was completed.

Oscar Bulkeley was graduated, with first honors, from Knox College, at Galesburg, Ill. with the class of 1905 as bachelor of science. He was 20 years old at this time, having taken but three years to complete his college course. In 1906 he went to Butte, Mont., wishing to gain practical experience in mining. He entered the mines of the Anaconda Copper company, taking up a pick and shovel and going down into the copper workings. His ability was soon recognized and before leaving he had attained the position of general purchasing agent.

In January, 1910, he entered the University of Illinois and was graduated there, in civil engineering, with the class of 1912. Immediately after graduating from the university he took the position of assistant superintendent of the water department at Rockford, Ill. He was married about this time to Edna Best of Los Angeles, Cal., the culmination of a school days' romance.

After serving at Rockford three years Mr. Bulkeley came to the water works in Jackson. Early in 1918 he entered the service of the government in the erection of the large powder plant being built near Nashville, Tenn. In the fall he was placed in charge of the entire water works system, a plant of great magnitude.

In January, 1920, he came to Lansing and became superintendent for the board of water and electric light commissioners which position he held until his death.

He was ever ardent in behalf of the best interests of his city and always gave aid toward building up Lansing. He was untiring in his efforts to work out the new street lighting system, the removal of overhead wires in the downtown section, and in the development of an adequate water supply, all with a broad vision of the future needs of the city. The city mourns the loss of a faithful servant and an ideal citizen in the full sense of the word.

He and Mrs. Bulkeley joined the Plymouth Congregational church soon after coming to Lansing. He always took an active part in its work.

Mr. Bulkeley was a member of Phi Gamma Delta and Tau Beta Pi societies. He was also a member of the American Society of Civil Engineers, the American Water Works Association, the Rotary club and the Masonic order.

He is survived by the widow, Edna Best Bulkeley; two children, Mary Louise and William Warren; and a brother, Claude A., of Wilmington, Del.

RESOLUTION ON DEATH OF MERRITT H. SMITH

WHEREAS through the death of Colonel Merritt Haviland Smith on December 9, 1926, the New York Section of the American Water Works Association has lost one of its most prominent and popular members, who by his personality endeared himself to all;

Therefore Be It Resolved that the members of the Section hereby recognize Colonel Smith's ability in water works matters, his efficient work for the City of New York as engineer and for the last thirteen years as Chief Engineer of Water Supply, his devotion to his country as evidenced by his service in the New York State Militia and the United States Army in the Spanish-American War, on the Mexican Border and in the World War, and the great loss his death entails to his many friends both within and without the American Water Works Association, and be it

Further Resolved that this resolution be spread upon the minutes of the New York Section, sent to the Publication Committee to be printed in the JOURNAL, and a copy be sent to Mrs. Merritt H. Smith.

ABSTRACTS OF WATER WORKS LITERATURE

FRANK HANNAN

Key: American Journal of Public Health, **12:** 1, 16, January, 1922. The figure 12 refers to the volume, 1 to the number of the issue, and 16 to the page of the Journal.

Why Boiler Tubes Burnt Out. G. C. REINHARD. Power, **63:** 51–3, 1926. From Chem. Abst., **20:** 1585, May 20, 1926. Corrosion of tubes in oil-fired boiler appeared to be related to formation of ferrous and ferric sulfates on tubes. Fused sulfates acted as flux for the iron, weakening tube enough to cause blistering and blowouts. The cleaner the tubes were, the more rapidly did corrosion occur.—*R. E. Thompson.*

Peculiar Examples of Corrosion of Boiler Parts. ROBERT STUMPER. Feuerungstechnik, **14:** 97–8, 1926. From Chem. Abst., **20:** 1585, May 20, 1926. Piece of open-hearth steel in contact with chromium-nickel steel lost about twice as much by corrosion as an isolated piece in same water. Anodic corrosion of bronze containing 2.4 per cent zinc occurred in boiler water having 0.5 gram sodium carbonate per liter.—*R. E. Thompson.*

Autogenous and Electrically Welded Boilers and Tanks (Holders). E. HÖHN. Z. Ver. deut. Ing., **70:** 117–22, 1926. From Chem. Abst., **20:** 1585, May 20, 1926. Comprehensive illustrated report on tests conducted for an association of steam boiler owners in Switzerland, covering welding by water gas, oxy-acetylene, and electric arc; comparisons with riveted joints and seams, etc.—*R. E. Thompson.*

Base-Exchanging Silicates for Purifying Water. Nordiske Natrolith Aktieselskab., Brit. 237, 626, July 25, 1924. From Chem. Abst., **20:** 1679, May 20, 1926. Substance suitable for removing iron, manganese, calcium, and magnesium from water is prepared by granulating clay, calcining it at 500–700° and then treating it with solution of alkali hydroxide or carbonate, e.g., boiling it for ¼ to 4 hours with solution corresponding to 1 per cent sodium oxide or 2 per cent sodium carbonate solution.—*R. E. Thompson.*

Welding Gray Cast Iron by Acetylene. F. POLITZ. Stahl u. Eisen, **45:** 653–8, 1925. From Chem. Abst., **20:** 1212, April 20, 1926. Thermal processes in welding gray cast iron were investigated. One end of rod, 21 mm. diameter and 150 mm. long, was heated by means of acetylene burner and temperature at various points throughout length were determined. Temperature on cooling was equalized throughout rod in 15 minutes. When end was heated to

melting point no temperature above pearlite point was recorded at 15 mm. distance. This localized heating in welding tends to set up strains which are liable to form cracks. In cold welding temperature differences in neighborhood of weld amount to about 1100°, but in hot welding whole object is heated to 900°, and differences are only about 200–250°. Except in highly strained parts, however, cold welding can be carried out without special precautions, as stresses are not so severe as generally assumed. Number of welds illustrating correct and faulty work were made and subjected to tensile and hardness tests and metallographic examination. In cold welding, structure of weld was fine-grained and contained ledeburite, but in hot welding it consisted only of pearlite and graphite. In latter case weld was softer, but withstood breaking load 50 per cent greater. Excess oxygen or acetylene, long heating, or overheating, deteriorated the weld. Addition of ferric oxide, up to 1.5 per cent, to welding powder favored formation of graphite on cooling and softened weld without reducing strength.—*R. E. Thompson.*

Preservative Coatings for Structural Materials. Rept. of Comm. D-1, Am. Soc. Testing Materials, **44**: 67 pp. (preprint) (June, 1925). From Chem. Abst., **20**: 1329, April 20, 1926. Results of tests, specifications and tentative methods of analysis. Tests seem to indicate that most rapid deterioration of paint occurs where it has been applied over badly rusted surface; sand blasting or pickling of steel seems preferable to hand cleaning. Fouling and corrosion appear to depend as much on variations in vehicle as on pigment.—*R. E. Thompson.*

Carbon Dioxide and pH Regulation of the Water by Some Fresh Water Algae. VLADIMIR ULEHLA. Ber. botan. Ges., **41**: 20–31, 1923; Botan. Abstracts, **14**: 729. From Chem. Abst., **20**: 1647, May 20, 1926. The algae studied responded quickly to change in H-ion concentration. Rapidity of response leads Ulehla to believe that cell membrane, instead of whole protoplast, is involved in reaction. He determined pH value for different green algae and divided them into 3 classes, pH boundaries of which were narrow. The carbon dioxide and hydrogen sulfide content actually determined the algal associations. Such algae as *Cladophora* and *Oedogonium*, with narrow pH limits, existed in standing water which showed strong fluctuations in H-ion concentration. They sometimes grew on different rocks, which acted as pH regulators. *Oedogonium* with pH 7.5–7.7 grew in strongly acid water. It was covered with incrustations called Psichohormium which are formed by bacterium *Sidomonas confervarum Chol.* Latter forms slimy ring around algal cells. This bacterium produces iron carbonate and calcium carbonate, which form incrustations on algae. The carbonate dissolves with increase of carbon dioxide, freeing OH ions, thus keeping down the H-ion concentration. Ulehla calls this relation "electrical symbiosis."—*R. E. Thompson.*

Modern British Practice in Water Softening. VI. Zeolite or Base-Exchange Plants. DAVID BROWNLIE. Ind. Chemist, **2**: 108–12, 1926; cf. C. A., **20**: 1479. From Chem. Abst., **20**: 1678, May 20, 1926. Following types of plants described and illustrated: (a) Boby-Azed, (b) Kennicott, and (c) Permutit.

"Doucil," used in type (a) differs from all other base exchange materials in being a colloid; it is a hard, rigid and homogeneous dried gel with approximate composition $Na_2O \cdot Al_2O_3 \cdot 5SiO_2$. Of the 13.3 per cent sodium oxide, about 10 per cent is active. Doucil is sold on 50 per cent moisture basis, and 1 ton (2240 pounds) will soften about 25,000 gallons of water of 20° hardness. "Kenzelite," used in type (b) is natural mineral zeolite. "Permutit B," used in type (c), is made from glauconite. Certain advantages are claimed for base-exchange products prepared from natural zeolites.—*R. E. Thompson.*

Washing and Sizing Sand and Gravel. EDMUND SHAW. Trans. Am. Inst. Mining Met. Eng., 1926, 1528–H, 10 pp. From Chem. Abst., **20:** 1695, May 20, 1926. Review, mentioning impurities to be removed, standard washing method, and means of determining water required for washing by decantation. Special washing methods outlined.—*R. E. Thompson.*

Tremie-Placed Concrete vs. Concrete Air Cured and Then Submerged. W. S. KINNEAR. Eng. News-Rec., **97:** 1048–9, 1926. Tremie-placed concrete of 1:3:6 mix when tested in compression one year after placing developed a strength ranging from 2740 to 4000 pounds per square inch, whereas concrete of same mix placed in air under almost ideal conditions developed a max. compressive strength of only 2,277 pounds per square inch.—*R. E. Thompson (Courtesy Chem. Abst.).*

Water-Intake Designed for Wide Distribution of Flow. MILTON G. SALZMAN. Eng. News-Rec., **97:** 998–1002 December 16, 1926. Detailed description of "draft-distributor" type of intake for power plants which is designed to draw water from large area of body of water without unduly disturbing natural flow conditions.—*R. E. Thompson.*

Theoretical Energy Losses in Intersecting Pipes. FRANK S. BAILEY. Eng. News-Rec., **97:** 1087, December 30, 1926. Two misprints in formulas given in article of J. C. STEVENS are pointed out.—*R. E. Thompson.*

Defense of the Price Current Meter. K. K. HOYT. Eng. News-Rec., **97:** 1010, December 16, 1926. Discussion of Price current meter in light of recent criticism by A. STAUS.—*R. E. Thompson.*

Construction of Great Water Power Plant Well Under Way. Eng. News-Rec., **97:** 1024–6, December 23, 1926. Illustrated description of progress on Conowingo hydro-electric development on Susquehanna River in Maryland, ultimate capacity of which will be 594,000 horse power. Dam is to be gravity section concrete structure approximately 4800 feet long and 104 feet high at highest point.—*R. E. Thompson.*

Treatment of Algae and Weeds in Lakes at Madison. BERNARD P. DOMOGALLA. Eng. News-Rec., **97:** 950–4, 1926. Tabulated data, illustrated graphically, of the microscopical content of the waters of the lakes at Madison, Wis., is given and the treatment of Lake Monona with $CuSO_4$ is described. Weeds

were removed by cutting and by the cable method. Arsenical compounds were found effective for destroying a variety of weeds. The study indicated that the soluble P and the different forms of N, as well as the type of bacteria present, were the growth-promoting factors for algae and weeds.—*R. E. Thompson (Courtesy Chem. Abst.)*

Finger Gates Control Flow of Tunnel Muck from Bunkers. Eng. News-Rec., **97**: 1044–5, December 23, 1926. Brief illustrated description of two types of finger gates employed in construction of Cascade tunnel of Great Northern Railway in Washington.—*R. E. Thompson.*

Improved Type of Copper Water Seal for Concrete Dams. C. E. Pearce. Eng. News-Rec., **97**: 1045–6, December 23, 1926. Illustrated description of improved type of seal for contraction joints in concrete dams devised during the designing of Exchequer Dam of Merced Irrigation District in California. Cost of seal installed was $2.20 per foot. This type of seal was also later used in Balch diversion dam of San Joaquin Light and Power Corporation and in Melones dam of Oakdale Irrigation District.—*R. E. Thompson.*

Heavy Rainfall and Runoff in Catskill Watershed, New York City. Wm. W. Brush. Eng. News-Rec., **97**: 1050, December 23, 1926. Data and comment on heavy rainfall and runoff in Esopus and Schoharie watershed gathering grounds as result of which it is considered necessary to use for the first time a coagulant to reduce the turbidity of the Catskill water.—*R. E. Thompson.*

Progress of Middle Rio Grande Conservancy Project. Eng. News-Rec., **97**: 904, December 2, 1926. Brief review of progress made by Middle Rio Grande Conservancy District which was organized in August, 1925, for purposes of irrigation, flood protection, drainage, river control, and water storage and distribution.—*R. E. Thompson.*

New Water Supply for Sao Paulo, Brazil, Brought 42 Miles. Eng. News-Rec., **97**: 945–6, December 9, 1926. New system now under construction for Sao Paulo has source of supply at head waters of Rio Claro, 42 miles from city and about 180 feet above distributing reservoir. Project includes 50-mile supply line consisting of 2.5 miles of tunnel, 27.5 miles concrete aqueduct and 20 miles riveted iron pipe some distance of which is in siphon, a dam impounding a lake at upper end of supply line, and a reservoir at lower end. Patent lining will be employed in pressure tunnel sections consisting of $\frac{3}{8}$ inch iron plates hydraulically pressed to form series of internally-flanged segments which can be bolted together as tunnel proceeds, forming continuous lining 8.5 feet in diameter.—*R. E. Thompson.*

Construction Methods and Plant at Martin Dam, Ala. L. G. Warren. Eng. News-Rec., **97**: 1064–71, December 30, 1926. Detailed illustrated description of plant and methods employed in construction of Martin dam and power house at Cherokee Bluffs, a storage power project on Tallapoosa River which will

create reservoir 39,400 acres in area and having capacity of 1,376,000 acre-feet for a drawdown of 60 feet.—*R. E. Thompson.*

Diagram for Flow through Venturi Meters. R. T. REGESTER. Eng. News-Rec., **97**: 716–7, 1926. A diagram is given showing the relation of head to water flow for standard Venturi meters.—*R. E. Thompson (Courtesy Chem. Abst.).*

Dolgarrog Dam Failure Blamed on Poor Foundation and Concrete. Eng. News-Rec., **97**: 873, November 25, 1926. Sir Alexander Gibb and Partners have reported that failure of Lake Eigiau dam was due to insufficient depth of foundations and concrete of poor quality which was not watertight. Proposals for reconstruction of reservoir include strengthening of existing wall concrete by cement grouting under pressure, reconstructing failed portion in concrete, providing reinforced-concrete facing and watertight concrete cutoff wall along whole length, providing new spillway and enlarging and concrete-paving north embankment.—*R. E. Thompson.*

Theoretical Losses in Intersecting Pipe Lines. Eng. News-Rec., **97**: 883–4, November 25, 1926. Further discussion of article of J. C. STEVENS by JULIAN HINDS, J. C. STEVENS and HAROLD A. THOMAS.—*R. E. Thompson.*

Serial Numbers on Fire Hydrants. SAMUEL P. BAIRD. Eng. News-Rec., **97**: 884, November 25, 1926. Suggestion that hydrants should be marked with serial number to facilitate identification.—*R. E. Thompson.*

Velocity at Tangent of Curves of 36-Inch Pipe. T. FARRANCE DAVEY. Eng. News-Rec., **97**: 905, December 2, 1926. Tests made to determine values of coefficient—mean average velocity divided by center velocity—for 36-inch reservoir discharge pipe under head of 80 feet at point of tangency of two curves (one reverse of other) showed that variation of coefficient from mean average coefficient was inappreciable, being 0.33 per cent over range of flow from 2 to 6 feet per second.—*R. E. Thompson.*

New Water Softening Plant for Hinsdale, Illinois. FRANK D. DANIELSON. Eng. News-Rec., **97**: 780–2, 1926. Illustrated description of softening and recarbonation plant at Hinsdale consisting of mixing tanks providing 20 minutes retention, clarifying basin equipped with Dorr clarifier providing 1 hour retention, settling basin providing 8 hours retention, carbonation basin, filters, and storage reservoir. Treatment of 1000 gallons of water requires 2.8 pounds $Ca(OH)_2$, $\frac{2}{3}$ pound 58 per cent Na_2CO_3 and $\frac{1}{3}$ pound alum. Chemicals are added in the mixing tanks, and sludge from clarifier is returned to these tanks also. Average total hardness is reduced from 472 to 100–130 p.p.m. CO_2 is produced by combustion of illuminating gas, 550 pounds per million gallons being applied, requiring 7,500 cubic feet of illuminating gas. Average cost of softening and carbonation is 6 cents per 1000 gallons. Initial cost of plant, which has nominal capacity of 2.3 m.g.d. and maximum capacity of 3 m.g.d., was $102,000.—*R. E. Thompson (Courtesy Chem. Abst.).*

Slide Rule for Submerged Orifices and Cipolletti Weirs. H. K. SMITH. Eng. News-Rec., **97**: 512–3, 1926. A brief description.—*R. E. Thompson (Courtesy Chem. Abst.).*

Do Baffle Piers Dispel Energy? Eng. News-Rec., **97**: 800–2, November 11, 1926. Discussion of paper of I. C. STEELE on this subject by ROBT. E. EWALD and reply to same by I. C. STEELE.—*R. E. Thompson.*

Differing Views on Use of Water Supply Reservoirs for Recreation. M. M. O'SHAUGHNESSY. Eng. News-Rec., **97**: 802, November 11, 1926. Condemnation of practice of employing water reservoirs for recreation.—*R. E. Thompson.*

Balch High-Head Power Project Well Under Way. Eng. News-Rec., **97**: 836–9, November 18, 1926. Illustrated description of progress on Balch hydroelectric development on Kings River in California. Project is first of series of 9 plants to be built by San Joaquin Light and Power Corporation on two branches of river to develop 500,000 h.p. from total head of 7,290 feet. Series of plants will involve 4 reservoirs, 14 dams, and 40 miles of conduit, chiefly in form of pressure tunnels. Balch plant will operate under head of 2243 feet (2381 feet static). Until Bucks Creek plant (2552 feet head) of Feather River Power Co. is completed this will be highest head plant in United States.—*R. E. Thompson.*

Tests of Large Riveted Joints of Various Steels. Eng. News-Rec., **97**: 864, November 25, 1926. Results of tests carried out at Bureau of Standards, reported by E. L. GAYHART, lead to conclusion that rivets softer than plate are better than rivets of equal strength or stronger, and that slip occurs at lead corresponding to about half usual rivet stress, or at shear of about 6,500 pounds per square inch.—*R. E. Thompson.*

Puddle Core Investigations at Tieton Dam, Washington. IVAN E. HOUK. Eng. News-Rec., **97**: 544–7, September 30, 1926. Results given of detailed core investigations made by Bureau of Reclamation during construction of Tieton hydraulic-fill on Yakima project. Details of methods included.—*R. E. Thompson.*

Structures on a Texas Water Service District. J. L. LOCHRIDGE. Eng. News-Rec., **97**: 748–51, November 4, 1926. Description of supply system of Wichita County Water Improvement District No. 1, completed in 1925, which was constructed primarily for water supply of Wichita Falls, Texas, but which provides sufficient water to irrigate about 100,000 acres along Wichita River and Holliday Creek. Construction of diversion dam and head works, canals, etc., described and illustrated.—*R. E. Thompson.*

Experimental Arch Dam Under Test Shows Anomalous Distortion. Eng. News-Rec., **97**: 828, November 18, 1926. Brief details given of results of tests of Stevenson Creek experimental arch dam of Engineering Foundation.—*R. E. Thompson.*

Gasoline Fire Used to Remove Cement Plaster in Reservoir. E. R. Oden. Eng. News-Rec., **98:** 495, March 24, 1927. Following unsuccessful attempt to stop leakage in concrete lined storage reservoir by applying thin troweled lining of cement over entire floor, it was decided to waterproof reservoir with "aquatite." It was found however that if cement plaster was not removed before coating with "aquatite," bulging occurred in heat of sun. Plaster was removed by flushing with gasoline and igniting, 90 per cent being removed at first firing and remainder at second. Gasoline used was 1 gallon per 75 square feet. Work was done without injury to old concrete.—*R. E. Thompson.*

Special Carriage Handles Penstock Sections on Steep Slope. Daniel McFarland. Eng. News-Rec., **98:** 498, March 24, 1927. Brief description of carriage in use on Kings River development of San Joaquin Light and Power Co., for handling sections of penstock pipe, grades on which are as much as 119 per cent.—*R. E. Thompson.*

Buried River in Illinois Furnishes Ground-Water Supply. W. D. P. Warren. Eng. News-Rec., **98:** 398–9, March 10, 1927. New 2-m.g.d. supply of Sullivan, Ill., derived from two 115-foot wells in buried, gravel-filled, preglacial valley of Kaskaskia River. Daily requirements for population of 2,500 is 250,000 gallons. Total cost was $210,000 and it is estimated that equal supply of surface water would have cost more than $1,000,000.—*R. E. Thompson.*

A Simple Water Aërator. James L. Barron. Eng. News-Rec., **97:** 634, 1926. Brief illustrated description of aërator consisting of inverted V-stack of horizontal staggered baffles which provide a cascade for the water, giving an even distribution and fine separation of flow. The aërator requires about 8–9 feet additional pumping head.—*R. E. Thompson (Courtesy Chem. Abst.).*

Los Angeles Flood Control. Eng. News-Rec., **98:** 62, January 13, 1927. Work has been actively under way on several dams, notably Pacoima dam, an arched concrete structure to be 375 feet high. Other structures under way are Santa Anita dam, Sawpit dam, and Puddingstone earth-fill dam.—*R. E. Thompson.*

American Falls Dam. Eng. News-Rec., **98:** 63, January 13, 1927. This dam is being built at American Falls on Snake River in Idaho to store water for irrigation. Dam is 4,756 feet long and 60 feet high, made up of concrete overfall and plain gravity sections and earth embankments. Storage capacity provided is 1,700,000 acre-feet. Dam is practically completed and storage of water was begun in October. Cost will be about $1,600,000.—*R. E. Thompson.*

Coolidge Dam. Eng. News-Rec., **98:** 63, January 13, 1927. Coolidge dam on Gila River in Arizona, being constructed for storage of irrigation water, is to be of new type called "multiple dome," 249 feet high and about 600 feet long, made up of 3 arch spans curved both horizontally and vertically. Contract was awarded December 2 for $2,268,525. Storage of about 1,300,000 acre-feet will be provided.—*R. E. Thompson.*

Conowingo Dam. Eng. News-Rec., **98:** 63, January 13, 1927. Brief review of progress on 4,800-foot dam and power house being built near mouth of Susquehanna River by Susquehanna Power Co.—*R. E. Thompson.*

How to Proportion Concrete Mixtures of a Desired Strength by the "Water-Ratio" Method. A. T. GOLDBECK. Cont. Rec., **40:** 968, 1926. Table is given showing the water-cement ratio required for concrete of various compressive strengths and practical proportioning procedure outlined.—*R. E. Thompson (Courtesy Chem. Abst.).*

Hetch Hetchy Water. Eng. News-Rec., **98:** 62, January 13, 1927. Work was completed early this year on San Francisco Bay crossing division with total of 21.8 miles of aqueduct, chiefly 60-inch steel pipe. Sixteen miles of tunnel are now under way. There is a gap of about 75 miles of tunnel and pipe line on which no work has been started. Estimated that first Hetch Hetchy water can be delivered to San Francisco peninsula in 1931.—*R. E. Thompson.*

Mokelumne Water Supply. Eng. News-Rec., **98:** 62, January 13, 1927. Some 27 miles of 65-inch pipe line have been completed and work is progressing, or has been completed, on approximately 19 miles of tunnels and other structures between Oakland and San Joaquin River crossing. Contract for Pardee dam at Lancha Plana site on Mokelumne River has been awarded. Work on remaining 46 miles of steel pipe aqueduct east of San Joaquin River is expected to start early in 1927 and delivery of Mokelumne River water into Oakland storage reservoirs is expected in 1929.—*R. E. Thompson.*

Los Angeles Water Supply. Eng. News-Rec., **98:** 62, January 13, 1927. Additional sources of supply in Owens Valley available for use in Los Angeles are being developed to supplement present Owens Valley aqueduct. Engineering studies are being made regarding construction of proposed aqueduct that would bring 1,500-second-foot supply from Colorado River, a distance of 268 miles, chiefly through desert country.—*R. E. Thompson.*

Boston Water Supply. Eng. News-Rec., **98:** 64, January 13, 1927. Progress briefly reviewed. Work is in charge of special body known as Metropolitan District Commission. Borings are in progress on line of Ware River tunnel and at sites of dams for proposed Swift River reservoir, authority to construct which has not yet been specifically granted. Ware River tunnel will be $12\frac{3}{4}$ feet in diameter and 12 miles long.—*R. E. Thompson.*

Tank Tower Wrecked by Twisting after Removal of Diagnonals. Eng. News-Rec., **98:** 121, January 20, 1927. Prief description of failure of 15,000-gallon wooden tank supported on 65-foot steel tower at Peabody, Mass. In cleaning and painting tower, several diagonal rods were disconnected. A short time later the tank rotated 180° around its vertical axis and collapsed.—*R. E. Thompson.*

Price Current Meter: Serviceability *vs.* Scientific Design. GERARD H. MATTHES. Eng. News-Rec., **98**: 126, January 20, 1927. Further discussion of Price current meter in which it is pointed out that while the unreliability of this meter for turbine testing has been clearly established, it has given dependable results in stream gaging for 30 years. The meter should not be used in turbulent or eddying types of flow. Requirements of serviceable current meter outlined.—*R. E. Thompson.*

Engineering News-Record Annual Statistics of Construction Costs and Volume. Eng. News-Rec., **98**: 73–9, January 13, 1927. Review of construction in 1927, Engineering News-Record index numbers of construction cost and volume, tabulation of "spring prices" of materials, discussion of employment prospects, and table of wage rates covering 4 trades in 4 cities for 1913–1926 inclusive.—*R. E. Thompson.*

Silicates in Portland Cement. P. H. BATES. Eng. News-Rec., **98**: 121, 1927. Evidence obtained in a study at Bureau of Standards is opposed to the existence of stable ternary compound of composition $8CaO \cdot Al_2O_3 \cdot 2SiO_2$, and likewise to existence of solid solutions of silicates and aluminates in this part of the system. It is concluded that the fibre-like crystals reported by some as $8CaO \cdot Al_2O_3 \cdot 2SiO_2$ are $3CaO \cdot SiO_2$.—*R. E. Thompson (Courtesy Chem. Abst.).*

Hydraulic Jump Formulas. FRANK S. BAILEY. Eng. News-Rec., **98**: 126, January 20, 1927. Pointed out that equation expressing condition for critical flow, viz.: that velocity head is one-half the depth, applies only to rectangular channels.—*R. E. Thompson.*

Reproduction-Cost-New Theory. JOSEPH JACOBS. Eng. News-Rec., **98**: 33, January 6, 1927. Discussion of "reproduction-cost-new" theory of valuation, in connection with recent United States Supreme Court decision in Indianapolis Water Co. case. Reproduction cost is of importance, but should not be and usually is not accepted as final and only measure of value, nor should current prices necessarily control in determining reproduction cost.—*R. E. Thompson.*

Concentrated Flow Erodes Rock Below Wilson Dam. HUGH P. ORAM. Eng. News-Rec., **98**: 190–2, February 3, 1927. Illustrated description of erosion at toe of 100-foot and 200-foot apron extensions of Wilson Dam on Tennessee River and methods employed in correcting same. Toe of apron was undermined in places to depth of 10 feet, slabs of rock weighing 200 tons or more having been carried downstream a distance of several hundred feet. To prevent further undercutting a concrete retaining wall was built abutting toe of apron, 4 feet wide at top with batter on downstream face of 1 foot in $3\frac{1}{2}$ feet and varying in height from 6 to 14 feet.—*R. E. Thompson.*

Novel Solution of Bridgeport Dam Spillway Problem. JOHN A. BEEMER. Eng. News-Rec., **98**: 108–112, January 20, 1927. Illustrated description of

Figuring Velocity of Approach in Dam Design. HARDY CROSS. Eng. News-Rec., **98**: 500, March 24, 1927. Brief discussion of kinetic pressure due to velocity of approach. Effect is small and is decreased by eddy losses.—*R. E. Thompson.*

Layout of Accessory Equipment in Modern Swimming Pool. J. FREDERICK JACKSON. Eng. News-Rec., **98**: 232–3, 1928. Brief illustrated description of a 60- by 25-foot pool in New Haven, Conn. Water purification equipment consists of 42-inch pressure filter and automatic apparatus for application of alum and bleaching powder.—*R. E. Thompson (Courtesy Chem. Abst.).*

Rio Grande Development Project in New Mexico. R. G. HOSEA. Eng. News-Rec., **98**: 400–1, March 10, 1927. Plans and progress made by Middle Rio Grande Conservancy District on project for systematic irrigation, land drainage, and flood protection over distance of 150 miles on Rio Grande outlined.—*R. E. Thompson.*

Iowa Flood of Cloudburst Type Damaged River Structures. E. W. DUNN. Eng. News-Rec., **98**: 405–6, March 10, 1927. Data given on flood in Sioux County resulting from heavy rainfall on September 17, 1926.—*R. E. Thompson.*

Erecting a High-Head Penstock on the Balch Project. Eng. News-Rec., **98**: 406–9, March 10, 1927. Illustrated description of construction of penstock on Balch project of San Joaquin Light and Power Corporation, which has static head of 2381 feet. Penstock, which is 4882 feet in length, was constructed of 40- to 60-inch banded pipe, fabricated in Poland, consisting of forge-welded core over which steel bands are shrunk. Joints are of single- and double-riveted bump types, double-riveted butt-strap and flanged. Two coats of tar paint were applied at factory and pipe was touched up after erection. Lower 250 feet of line was embedded in concrete.—*R. E. Thompson.*

New York to Build 4 Miles of Shield Tunnel Under Difficult Conditions. Eng. News-Rec., **98**: 328–31, February 24, 1927. Details of two-tube tunnel, 9104 feet in length, to be driven through fine sand under East river.—*R. E. Thompson.*

Ten-Inch Wood Stave Pipe Line has Suspended Span 275 Feet Long. Eng. News-Rec., **98**: 162–3, January 27, 1927. Brief description of 10-inch wood-stave pipe line which was suspended across canyon on 1-inch steel cables during construction of Lake Cushman Dam for Tacoma, Wash. Little sagging occurred when line was subjected to pressure of 175 pounds per square inch.—*R. E. Thompson.*

Equipment Worth $1000 per Man Employed in Rush Earth-Fill Dam Job. Eng. News-Rec., **98**: 334–5, February 24, 1927. Brief details of equipment and methods employed in construction of Philbrook dam, a rolled earth fill, for Pacific Gas and Electric Co., on west branch of North Fork of Feather River. Dam is 90 feet high and contents total 142,000 cubic yards. Capacity of

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Economic Diameter of Water Pipe Lines. Eng. News-Rec., **98:** 499–500, March 24, 1927. Mathematical discussion of paper of J. W. LEDOUX by RALPH W. POWELL and reply to same by J. W. LEDOUX.—*R. E. Thompson.*

Water Rates of Milwaukee Upheld by the Wisconsin Railroad Commission. Eng. News-Rec., **98:** 451–3, March 17, 1927. Uniform meter rate for all water sold by Milwaukee water works within city and higher, but also uniform, rate for metered water sold outside city has been approved by Railroad Commission of Wisconsin. Commission holds that there is wide range between what large and small consumers actually pay for water owing to fact that first cost of main extensions, service connections, and meters is met by meter users and meter charge is same for all consumers. Commission also approves fire protection charge of $10 per hydrant paid by city, although holding that revenue thus afforded does not equal cost of providing and maintaining hydrants alone without making allowance for capital and operating costs of mains and pumping stations. Water works as whole is not giving proper return on investment. Commission bases its approval on its opinion that as rates are not excessive, unjust, or unjustly discriminatory, city is entitled to exercise managerial discretion as to what rates shall be.—*R. E. Thompson.*

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Density of Concrete and the Water-Cement Ratio. F. R. MCMILLAN. Eng. News-Rec., **98:** 445–7, 1927. Graphically illustrated discussion of relationship of water-cement ratio to density and permeability, which leads to conclusion that to be watertight, concrete must be placed in plastic condition, must have a low water-cement ratio, and must be thoroughly cured. In computing the amount of solid matter (density), the quantity of combined water should be added to the absolute volumes of cement and aggregate. The imperviousness is determined by the amount of free or uncombined water.—*R. E. Thompson (Courtesy Chem. Abst.).*

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Annual Yield of Driven Wells at Lowell, Mass. ROBT. J. THOMAS. Eng. News-Rec., **98**: 369, March 3, 1927. Tabulated data given showing annual yield of driven wells from which Lowell has obtained its water supply for 32 years. Construction cost of well supply, $700,000, was lower than for surface supply, but cost of pumping is high as water has to be pumped twice. Cost of pumping and filtering last year was $50 per m.g. Supply is just adequate and as further ground water is unobtainable, State Department of Health is now advising that surface supply be developed.—*R. E. Thompson.*

In Defense of Current Meters. BENJAMIN F. GROAT. Eng. News-Rec., **98**: 370, March 3, 1927. Further discussion of current meters with tabulation showing comparison of turbine discharges determined by means of 3 types of current meters and by chemical method. If extreme accuracy is required, as in turbine testing, it is necessary to employ more than one type of meter, unless most unusual conditions of quiet flow exist, as in long, straight, uniform canals. Meters of cup type over-register in turbulent flows while those of propeller type under-register, and discrepancy is criterion of degree of error.—*R. E. Thompson*

Conditions and Prospects on the Colorado Delta. Eng. News-Rec., **98**: 439–44, March 17, 1927. Three articles, as follows: **1. Imperial Valley Views on the Colorado Delta Situation. 2. Channel and Levee Conditions on the Colorado Delta.** R. M. PRIEST. **3. Colorado Delta Silting Causes Serious Flood Menace.** J. C. ALLISON.—*R. E. Thompson.*

Heavy Autumn Rainfall in Illinois in 1926. CLARENCE J. ROOT. Eng. News-Rec., **98**: 327, February 24, 1927. Data given on severe rains and widespread flood conditions throughout central Illinois, supplemented by information in paper from office of Pearse, Greeley, and Hansen. Comparison of 5-day rainfall and 10-day runoff given in latter indicates that for Mackinaw River the discharge was 6.68 inches and the rainfall 15 inches, while on Sangamon River the respective figures were 7 and 20 inches.—*R. E. Thompson.*

Echo Reservoir to be Built. Eng. News-Rec., **98**: 355, March 3, 1927. Weber-Provo reclamation project in Utah has been approved and construction will be proceeded with. Central feature is 74,000-acre-foot (Echo) reservoir on Weber River. Dam will be earth embankment of 125 feet maximum height and 1800 feet length, containing 1,400,000 cubic yards of material, with water face riprapped 4 feet thick. A 25-mile upstream canal will be excavated from the Weber to the Provo River to enable diversion of water from reservoir into latter river to increase low-water flow. Cost will be $3,000,000.—*R. E. Thompson.*

Tentative Conclusions from Arch Dam Test at Stevenson Creek. Eng. News-Rec., **98**: 450, March 17, 1927. Brief tentative conclusions.—*R. E. Thompson.*

Charts Check Costs and Progress in Dam Building. DAN PATCH. Eng. News-Rec., **98**: 480–1, March 24, 1927. Description of cost and progress charts developed by author.—*R. E. Thompson.*

ABSTRACTS, SUB-COMMITTEE NO. 9

JOINT RESEARCH COMMITTEE ON BOILER FEEDWATER STUDIES

Experience and Progress in Treatment of Boiler Feedwater (Neuere Erfahrungen und Fortschritte in der Behandlung des Kesselspeisewassers). E. GUTMANN. Dinglers polytechnisches Jl., **108**: 3, February, 1927, pp. 29–31. Points out that one of newest and most noteworthy means of preventing boiler scale is known under trade name of Kespurit, which has been in successful use for several years; it is water-soluble colloid enveloping smallest scale-forming constituents, which are thus prevented from wandering as insoluble colloids in boiler.

Principal Methods of Boiler-Feedwater Treatment (Kritik der hauptsächlichsten Methoden zur Reinigung von Kesselspeisewasser). Wärme- u. Kälte-Technik, **29**: 4, February 23, 1927, pp. 46–50. Discusses Permutit, lime-soda, and Neckar processes.

Thermal Methods of Feedwater Treatment (Die thermische Speisewasseraufbereitung). R. BLAUM. V. D. I. Zeit., **71**: 9, February 26, 1927, pp. 285–290, 12 figs. Exhaust-steam evaporator makes no additional demand on boiler and heat content in evaporated steam as regained in feedwater preheater; under these conditions, evaporator ceases to be emergency device and becomes regular element of power plant; author recommends two-stage preheating; in one stage auxiliary steam is available at high pressure, and other at low pressure; degasification of water can be best carried out in mixed preheaters; under land installations most important factor to be considered is very large scale of operation; heat loss in central stations can be kept good deal below that on shipboard; author shows that it is possible to find proper solution for problem of water distillation, whether boiler is equipped with economizers or regenerators and air preheaters; described central-station installation where bled steam is used for heating and water raised to temperature of 65 deg. cent. See brief translated abstract in Mech. Eng., vol. 49, no. 5, May, 1927.

Overcoming Boiler-Water Troubles with Tri-Sodium Phosphate. B. C. SPRAGUE. Power, **65**: 9, March 1, 1927, pp. 321–322, 1 fig. Sulphate waters will not cause adherent scale if enough sodium carbonate is added to maintain certain ratio between carbonate and sulphate in boiler water; at high operating pressures, however, most sodium carbonate decomposes into sodium hydroxide, making it difficult to maintain desired ratio; this difficulty can be avoided by use of tri-sodium phosphate.

Boiler Scale and Its Prevention (Sur un cas d'incrustation des chaudières alimentées avec de l'eau épurée et le moyen de l'éviter). P. LETELLIER and

H. SUNDER. Chimie & Industrie, **16**: 3, September, 1926, pp. 241–242. Describes process of treating feedwater by replacing adequate quantity of sodium phosphate by phosphoric acid.

Apparatus for Deaërating Boiler Feed Water. W. S. ELLIOTT. Brit. 247,342, Dec. 18, 1924. Chem. Abst., February 20, 1927, **21**: 4, 620.

Apparatus for Treating Boiler-Feed Water. Babcock & Wilcox, Ltd., and A. SPYER. Brit. 245,664, June 16, 1925. Chem. Abst., January 20, 1927, **21**: 2, 294. A de-aërator, evaporator, liming app., and filter are provided.

Bent-Tube Evaporator for Treating Sea Water for Use in Boilers, etc. R. C. JONES, U. S. 1,617,119, February 8, Chem. Abst., March 20, 1927, **21**: 974.

Boiler Feedwater Treatment by Permutite System. CLARENCE BAHLMAN. Fifth Ann. Rept. Ohio Conference Water Purification. 1925, 64–7, Chem. Abst., November 10, 1926, **20**: 21, 3524.—*R. E. Greenfield.*

Case of Scaling of Boilers Fed with Softened Water and Method of Preventing It. P. LE TELLIER and H. SUNDER, Chimie et industrie Special No., 241–3 (September, 1926). Chem. Abst., March 10, 1927, **21**: 785. $CaSO_4$-bearing boiler water which had been softened (presumably in the cold) by the CaO-Na_2CO_3 processes to 4–5° of hardness (French), 0.5–2° NaOH and 3–5° total alkali, caused heavy $CaSO_4$ scaling in a boiler by reversal at high temp. of the reaction taking place in softening ($Na_2SO_4 + CaCO_3 \rightarrow Na_2CO_3 + CaSO_4$). Another water containing but little SO_4 and softened in the same manner gave but a very thin pulverulent deposit on the tubes in 1 year. Renewal of the trouble was prevented by adding 0.1 kg. $Na_2HPO_4 \cdot 12H_2O$ per cubic meter as the water was being fed to the boiler. The Ca is eliminated (presumably as $Ca_3(PO_4)_2$) in the form of a fine sludge, requiring rather frequent blow downs and occasional cleaning out of the boilers, and scaling is practically completely eliminated. To prevent the Na_2CO_3 content from rising above 0.5 g. per liter, 0.0175 liters of 45° Bé H_3PO_4 per cubic meter of water was also added.—*A. Papineau-Couture.*

Distilling Boiler Feed Water. International General Electric Co., Inc. Brit. 247,567, February 10, 1925. Chem. Abst., February 20, 1927, **21**: 4, 620.

The Economy of Boiler Water Heaters in Feeding Steam Boilers. Anon. Genie civil **87**: 359, 1925. Chem. Abst., July 10, 1926, **20**: 2217. The apparatus of GABARINO, of Milan, is described. This app. consists of a boiler with an inner tube closed at one end into which cold feed water is fed by a delivery pipe entering the open end of the inner tube. The water is carried nearly to the closed end of the inner tube and withdrawn from the boiler after having been passed through the inner tube to its opening and then back to the other end of the boiler. Advantage is claimed for the device since any gases attack the inner tube and not the boiler and better circulation and more uniform heating result.—*Jack J. Hinman, Jr.*

Evaporator Adapted for Purifying Boiler Feed-Water. J. PRICE. U. S. 1,617,081, February 8. Chem. Abst., March 20, 1927, **21**: 974.

Feed Water Treatment in Power Plants. Anon. Power Plant Eng., **31**: 25–9, 1927. Chem. Abst., February 10, 1927, **21**: 3, 467. The use of evaporators with de-aërators has become general. H_2SO_4 has been successfully used to maintain the proper $SO_4 : CO_3$ ratio. The use of Na phosphate has not always been satisfactory.—*K. C. Beeson.*

Modern Practices in Boiler Feed Water Treatment. A. SPLITTGERBER, Z. angew. Chem., **39**: 1340–5, 1926; cf. C. A. **20**: 790 Chem. Abst., **21**: 4, 619. February 20, 1927. To protect the boiler from acid corrosion the alkali content should not be less than 0.4 g. per liter of caustic soda or 1.85 g. per liter of soda ash. This concentration at 200° gives a pH about 9.4 and is not injurious. Tests on well-made boilers show that rivet hole fissures are not caused by high concentration of caustic if heavy scale is not present.—*K. C. Beeson.*

Preventing Formation of Adherent Scale in Steam Boilers. R. E. HALL, U. S. 1,613,656, January 11. Chem. Abst., March 10, 1927, **21**: 786. H_2O used in steam boilers and which contains scale-forming constituents such as Ca and Mg compds. is mixed with a suitable proportion of a substance such as Na_3PO_4 which reduces the tendency to form an adherent scale in the boiler. U. S. 1,613,701 relates to a similar process in which Na_2CO_3 may be used to form non-adherent sludge.

Preventing Incrustation in Boilers. G. BOLOGNE and W. DRYBUSCH. Brit. 249,431, October 27, 1925. Chem. Abst., March 20, 1927, **21**: 974. Zn plates are partly immersed in the H_2O as are also battens of alder wood so that the sap may be gradually extracted from the wood.

Railroad Water Treatment. R. E. COUGHLAN, J. Western Soc. Eng., **31**: 392–4, 1926; cf. C. A. **20**: 3758. Chem. Abst., January 10, 1927, **21**: 2, 293. Treatment of waters with excess of lime and soda over that required to combine with scale-forming materials is satisfactory in preventing corrosion.—*K. C. Beeson.*

Recent Developments in Feed-Water Treatment. E. H. TENNEY. Power Plant Eng., **31**: 23–4, 1927. Chem. Abst., February 10, 1927, **21**: 3, 467.—*K. C. Beeson.*

Recorder for Dissolved Oxygen in Feed Water. Anon. Engineering, **122**: 610, 1926. Chem. Abst., January 20, 1927, **21**: 2, 293.—*K. C. Beeson.*

Report of the Bureau of Boiler Inspection. WM. E. SMITH. Proc. Hawaiian Sugar Planters Assoc., 45th Ann. Meeting 1925, 1–20, 1926; cf. C. A. **20**: 1291. Chem. Abst., March 10, 1927, **21**: 785.—*K. D. Jacobs.*

Water Purification. A. L. GRANT. Can. 258,297, February 23, 1926. Chem. Abst., November 10, 1926, **20**: 21, 3526. $BaSiO_3$ is added to heated water containing $MgCO_3$ to remove scale-forming substances from the water and avoid substitution of foam-producing or soluble salts in the water.

NEW BOOKS

Guide to Swiss Hydraulic Developments. 1926 Edition (English). Zürich, Switzerland: Secretariat of Association for Utilization of Hydraulic Power. Cloth; 6 by 9 inches; pp. 538. Reviewed in Eng. News-Rec., **97**: 1005, December 16, 1926.—*R. E. Thompson.*

Report on an Investigation of Lake Michigan in the Vicinity of South Chicago and the Calumet and Indiana Harbors. H. R. CROHURST and M. V. VELDEE. Obtainable from Officer in Charge, Stream Pollution Investigations, U. S. Public Health Service, Cincinnati, Ohio. $3.40. B. coli data and brief outline of conclusions regarding pollution given in Eng. News-Rec., **97**: 1032, December 23, 1926.—*R. E. Thompson.*

Die Auskleidung von Druckstollen und Druckschacten. OTTO WALCH. Berlin: Julius Springer. Paper; 6 by 9 inches; pp. 188. Reviewed in Eng. News-Rec., **98**: 286, February 17, 1927.—*R. E. Thompson.*

Concrete Practice. GEO. A. HOOL and H. E. PULVER. New York and London: McGraw-Hill Book Co., Inc. Cloth; pp. 369. $3. Reviewed in Eng. News-Rec., **98**: 287, February 17, 1927.—*R. E. Thompson.*

Design and Construction of Formwork for Concrete Structures. A. E. WYNN. London: Concrete Publications Ltd. Cloth; 5 by 8 inches; pp. 296. 20s net. Reviewed in Eng. News-Rec., **98**: 288, February 17, 1927.—*R. E. Thompson.*

Water Power Engineering. H. K. BARROWS. New York and London: McGraw-Hill Book Company, Inc. Cloth; pp. 734. The author begins his treatment of the subject with a short sketch of the historical development of equipment for the utilization of water power. This is followed by data on the distribution of potential water power throughout the world, as contrasted with that actually developed. While the consideration of these is not absolutely essential to an understanding of the basic principles of water power engineering, the author has used them in a very interesting manner to illustrate the outstanding factors governing the usefulness of such power.

Two of the essential elements in a water power development are stream flow and available head or fall. Stream flow is subject to so many governing factors that it is apparent considerable study should be given this item. The author's treatment of this is in somewhat greater detail than usual. The principles of Hydrology, as applicable to the subject, are treated quite interestingly in Chapter II, so that the student or engineer is given a very clear picture of

the factors, in spite of the complexity of the interrelations. Chapter III deals with the correlation of stream-flow data, particularly with regard to duration curves and storage. Available head and power are also discussed in this chapter.

The fourth chapter is upon the turbine equipment and general arrangement of the plant. The trend in development of more efficient units is traced. Theoretical features of design are also considered.

In turn, the dam, waterway canals and penstocks are considered in Chapters V and VI. As affecting the location and costs, factors are given which should be covered by preliminary and final investigations, the foundation for the dam being the principal item. Various types of dams are considered with application of theoretical principles to their design. The waterways, such as canals and penstocks, are considered in much the same manner.

Chapter VII treats of the power house and its equipment. A table is included in this chapter with principal details of design of 47 different plants. Illustrations are also given of typical installations.

The electrical plant equipment is not dwelt upon in great detail; however, the essential elements are covered. Considerable space is devoted to the details of the transmission line and rightly so since it is one of the most important factors affecting the economy of the undertaking.

A separate chapter has been devoted to the theoretical elements of speed and pressure regulation. Illustrations are also included of typical regulating equipment.

The author has used quite freely examples and data in table form to support his views and conclusions. It is quite pleasing to find that the arrangement is such that the interest is held. He has devoted considerable attention to the practical and economical side. This should be appreciated since such great economies have been effected in recent years in the steam power plant field. There is no doubt that this fact will tend to an improvement in the overall cost of hydro-electric power by lessening the capital outlay, operating costs and power losses.—*Frank Quarles.*